Utilization of FATS in Poultry and Other Livestock Feeds

TECHNOLOGY AND FEEDING PRACTICES

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Utilization of FATS in Poultry and Other Livestock Feeds

. . Technology and Feeding Practices . .

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SUMMARY

Numerous changes in our agricultural economy and in our scientific knowledge of feedstuffs have led to an enormous increase in the use of added fats in feeds since 1954. Fats are now known to be essential components of animal feeds, and currently more than 500 million pounds of added fats are used annually.

With this vast expansion in use, important problems have arisen, such as specifications for fats suitable for feed use, effectiveness of and methods for incorporating suitable antioxidants, storage and handling of fats, and mixing of fats into finished feeds. Moreover, many studies have been made that relate the use of fat to the nutritional requirements of our various domestic animals and thus serve to delineate the most favorable conditions for adding fats to their respective rations.

Results of the studies pertinent to the use of fats in feeds have been published in a wide variety of journals and trade magazines. It has been the object of this report to bring together in one place a comprehensive, but not necessarily a complete, review of available information in this field. It is hoped that this review will aid those now engaged in the preparation or use of feeds containing added fats and will encourage even further use of fats by pointing to their potential advantages.

NEED FOR THIS STUDY

Fats are essential components of food and feeds for man or beast. From a nutritional viewpoint they are high energy foods; they yield about 9 Calories per gram when metabolized, whereas starch and protein each yield only approximately 4 Calories per gram. Moreover, most fats, including the animal fats, contain linoleic acid and other polyunsaturated fatty acids which are essential in the diet of most animals. Finally, fats act as carriers and protectors for several of the important fat-soluble vitamins and antioxidants.

Despite these nutritional values, fats as such were not added to livestock feeds in this country to any extent before about 1954 for several reasons--the relatively high cost of fats, uncertainty regarding their stability to oxidation, and because most of our seed meals before that time contained more than 5 percent of fats. Seed meals are the chief source of proteins and therefore constitute a principal ingredient of nearly all of our mixed feed production. With the close of World War II, however, a series of changes began which have completely altered this picture.

First, the inedible animal fats (for human purposes) became much cheaper than before. These fats are inexpensive, plentiful, recurring natural resources obtained as byproducts of the domestic livestock industry. Because they are byproducts their production cannot be controlled; in fact, it increases as meat production increases. The growing production of inedible animal fats, coupled with increasing competition from synthetic detergents in their most important outlet (soap), has resulted in large domestic surpluses of these fats. In the 1958 crop year about 2.75 billion pounds were produced--an excess of more than 1 billion pounds above our domestic demand. Although most of this annual surplus has been successfully exported, the increased production and decreased domestic demand have inevitably led to very low prices. In fact, for several years grease and tallow have been available at prices below 5 cents per pound, making them a cheap source of Calories.

Since fats serve primarily as a source of Calories or energy in animal feeds, they must compete pricewise with the cheapest

[1] Location: Philadelphia 18, Pa.

nonfat source of energy. Ordinarily this source is corn. By calculation, good quality corn contains 3.5 Calories per gram, whereas fats contain 9 Calories per gram. Thus fats are about 2.56 times as rich in Calories as corn and, on that basis, have a value of about 2.5 times the cost of corn. It is true that corn provides some protein, vitamins, and minerals, but in inappreciable amounts at the levels at which fat may be used most advantageously. Thus when corn sells at 3 cents per pound, the minimum comparative energy value of fats must be about $7\frac{1}{2}$ cents per pound. However, 90 to 95 percent of the fats are digested and absorbed, whereas only 80 percent of the corn is utilized, according to Morrison's tables (1956).

A second change that has made the potential outlook for the use of fats in feeds appear more promising is the development of inexpensive, effective antioxidants for edible-grade fats. Before this development the addition of fats to feeds was viewed with uncertainty and skepticism, because of the known tendency of tallows and greases to become rancid and cause loss of nutritive value and palatability. It seemed likely that these antioxidants would also be helpful in overcoming the problem of rancidity in fat-supplemented feeds.

A third important trend that has contributed to the potential of animal feeds as an outlet for inexpensive grades of fats is the increasing application of solvent extraction processes to oilseeds, such as soybeans. Seed meals regularly produced by these processes have an oil content of less than 1 percent as compared with 5 percent or more by the older pressing methods. The use of extracted meals as a principal ingredient in mixed feeds has not only resulted in products with lower energy or fat content per unit weight but also has led to other undesirable characteristics, such as increased dustiness and unattractive appearance. Dustiness causes undesirable working conditions in feed mills and losses of feed, particularly when feeding is done in places exposed to wind.

The first comprehensive investigations on the feasibility of supplementing animal feeds with inexpensive grades of fat (tallows and greases) were carried out under contract with the U.S. Department of Agriculture by the American Meat Institute Foundation (1950-53). The favorable results obtained stimulated a great deal of research in this field and promptly led to substantial commercial production of feeds containing added fats. Currently, about 500 million pounds of tallows and greases are being incorporated annually in commercial mixed feeds for livestock. This increasing use of fats in feeds, as might reasonably be expected, has given rise to certain problems and questions of interest to the fat producer, the feed manufacturer, the livestock grower, and animal nutrition investigators. Hence, there is need for a comprehensive review of the development which may furnish answers to many of these questions and also suggest improved practices for the most economical and safe utilization of fats in this important outlet.

TECHNOLOGY OF UTILIZATION OF FATS IN FEEDS

GRADES AND QUALITY OF FATS

Early work on the use of fat in feeds at the American Meat Institute Laboratories was performed with white grease and prime tallow. High grade fats were deliberately chosen to avoid complicating the conclusions by questions of possible contaminants in the fats. Obviously the glycerides and their principal chemical constituents, i.e. glycerol and the n-alkyl fatty acids having an even number of carbon atoms, are valuable feed components. This means that all the common fats and oils, as well as the fatty acids or simple esters derived from them, may usually be considered to be desirable components of feeds when used in the proper proportions with other materials essential to supply the needed nutritional characteristics. Commercial development concerned with the use of fats in feeds, however, quickly led to inquiries concerning not only the possible use of lower grades of animal fats but also the use of other inexpensive fatty materials.

The grading of inedible fats developed over the years has pertained almost solely to their value for use in soap. With experience in the use of fats in feeds came the realization that the accepted methods for grading fats leaves something to be desired when the fats are intended for use in feeds. The presence of free fatty acids, for example, is not so objectionable when the fat is to be used in feeds, except insofar as it may be indicative of careless handling. The soapmaker, however, finds high free fatty acids undesirable in large part because

his valuable glycerol byproduct yield is reduced.

Definitions and Descriptions

Uncertainty and even confusion in the naming, grading, and classification of fats for use in feeds led the Executive Committee of the Association of American Feed Control Officials (1958) to recommend the adoption of the following tentative definitions:

"Animal fat" is the product obtained from the tissues of mammals and/or poultry in the commercial processes of rendering or extracting. It consists predominantly of glyceride esters of fatty acids and contains no additions of free fatty acids or other materials obtained from fats. It shall contain not less than 90 percent of total fatty acids, not more than 2.5 percent of unsaponifiable matter and not more than 1 percent of insoluble matter. If the product bears a name descriptive of its kind or origin, for example, 'tallow,' 'lard,' 'grease,' it must correspond thereto. If an antioxidant (or antioxidants) is used, the common name or names shall be indicated, followed by the word 'preservative' or 'preservatives.'

"Vegetable fat" (or oil) is the product of vegetable origin obtained by extracting the oil from seeds or fruits which are commonly processed for edible purposes. It consists predominantly of glyceride esters or fatty acids, not more than 2 percent of unsaponifiable matter, and not more than 1 percent of insoluble matter. If the product bears a name descriptive of its kind or origin, for example, 'soybean oil,' 'cottonseed oil,' it must correspond thereto. If an antioxidant (or antioxidants) is used, the common name or names shall be indicated, followed by the word 'preservative' or 'preservatives.'

"Hydrolyzed fat" or oil (feed grade) is a product obtained in the fat processing procedures commonly used in edible fat processing or soap making. It consists predominantly of fatty acids and shall contain not less than 85 percent of total fatty acids, not more than 6 percent of unsaponifiable matter and not more than 1 percent of insoluble matter. Its source shall be stated in the product name, for example, 'hydrolyzed animal fat,' 'hydrolyzed vegetable oil,' 'hydrolyzed animal and vegetable fat.' If an antioxidant (or antioxidants) is used, the common name or names shall be indicated, followed by the word 'preservative' or 'preservatives.'

" - - Ester - - " (feed grade) is the product consisting of methyl, ethyl or other non-glyceride ester of fatty acids derived from animal and/or vegetable fats. It consists predominantly of the ester and shall contain not less than 85 percent of total fatty acids, not more than 10 percent of free fatty acids, not more than 6 percent of unsaponifiable matter, and not more than 1 percent of insoluble matter. Its source shall be stated in the product name, for example, 'methyl ester of animal fatty acids,' 'ethyl ester of vegetable oil fatty acids.' If an antioxidant (or antioxidants) is used, the common name or names shall be indicated followed by the word 'preservative' or 'preservatives.'

"Fat product" (feed grade) is any fat product which does not meet the definitions for animal fat, vegetable fat or oil, hydrolyzed fat or fat ester. It shall be sold on its individual specifications. If an antioxidant (or antioxidants) is used, the common name or names shall be indicated, followed by the word 'preservative' or 'preservatives.'

Note--The use of the term 'feed grade' requires that the specific type of product will have been adequately tested to prove its safety for feeding purposes.

Specifications

The following standards for analytical characteristics and physical properties were approved by the Nutrition Council of the American Feed Manufacturers Association (1957).

Analyses: (Basis, American Oil Chemists' Society, Official and Tentative Methods, current edition unless specified.)

1. Stability: A.O.M. Test (Active Oxygen Method). Twenty hours of A.O.M. stability is the minimum acceptable and is approximately equivalent to 320 days of storage life.

2. Purity: M.I.U. (Moisture, Insolubles, Unsaponifiables). The M.I.U. is on the basis of 2 percent unless

otherwise specified. Excessive moisture causes rapid deterioration and must be kept out of animal fat. Higher percentages of impurities proportionately reduce caloric values.

3. Antioxidant: Only approved antioxidants shall be used, and in sufficient quantity to meet minimum stability requirements.

4. Free Fatty Acid: (FFA) Free fatty acid varies, but for feeding purposes, animal fats having a free fatty acid content not exceeding 15 percent are usually selected.

Physical Properties:

1. Color: Color is an indication of grade, but has little or no effect on feeding quality.

2. Titer: (Approximate Melting Point). Titer is the solidification point of the fatty acid measured in degrees Centigrade. Fat having a titer of 40° C. and above is called tallow. Fat having a titer below 40° is called grease.

Analytical Characteristics

Color and free fatty acid content of fats for feeds apparently have little or no effect on the feeding quality or efficiency of utilization by chicks according to Hathaway et al. (1959). In general, however, very dark fats and fats with a high free acid content are less desirable, because they are often indicative of uncertain origin, poor handling, and inferior source materials. Consequently, intermediate and best grades of tallows and greases having not over 15 percent of free fatty acids are preferred and recommended.

Total fatty acids (TFA) comprises both the free fatty acids and those combined with glycerol as glycerides in the fat, and amounts to 92 to 94 percent of the whole animal fat or vegetable oil. Since most of the energy of fats is supplied by TFA, this value is a good index for comparing energy values for different fats.

Unsaponifiable matter in fats has received considerable attention in the past several years, owing to an unfortunate mistake of including abnormal fatty materials with normal renderers' fats. The abnormal material was high in unsaponifiable matter and this produced chick edema, resulting in the death of a large number of chicks. It should not be concluded from this, however, that all unsaponifiable matter is harmful or undesirable in fats. All normal fats contain some unsaponifiable matter largely composed of sterols, vitamins, and pigments which are not harmful and are metabolized and utilized. However, since unusually high unsaponifiable content may indicate the presence of abnormal fatty material it seems desirable to place a limitation on the allowable levels, such as 2.5 percent in animal fats, 2 percent in vegetable oil, and 6 percent in hydrolyzed fat and esters.

Insolubles in fats usually consist of small particles of fiber, hair, hide, bone, metal, and soil. While they generally are not harmful, their presence in substantial amounts can damage or clog handling equipment at the feed mill, such as storage tanks, pumping lines, screens, and nozzles. Hence, a limit of 1 percent of insoluble matter has been recommended.

Moisture in fats for feeds is detrimental, because it induces corrosion in equipment, increases free fatty acids by hydrolytic action on glycerides, and may accelerate rancidity resulting from the formation of rust, for rust is a powerful promoter of rancidity. Moisture, as well as insolubles, obviously must be considered as diluents of fats and, if present in more than minimal allowable proportions, would justify price reduction.

Metabolizable energy (M.E.) values of various fats for chicks have been reported by two groups of investigators. The evaluation of fats for use in feeds by this direct approach obviously has a great deal of merit but is difficult. Moreover, the values for a given type of fat may vary considerably, depending on the quality of the particular sample and also on the proportion used in the basal diet. In general, the data shown in table 1 indicate higher M.E. values for the more unsaturated fats and lower values for the fatty acids than for the fats from which they were derived. However, in practical feeding experiments with chicks, Hathaway et al. (1959), as mentioned previously, found that replacing animal and/or

vegetable fat with the same amount of comparable fatty acids had little or no effect on gain in weight and feed efficiency for chicks. Combs, Helbacka et al. (1958) also obtained results pointing to the same conclusion.

TABLE 1.--*Metabolizable energy values of fats and fatty acids for chicks*

Fatty material	Metabolic energy[1]	Metabolic energy[2]
Edible fats:	*Cal./lb.*	*Cal./lb.*
Corn oil	3,950	--
Soybean oil	4,210	--
Lard	3,980	--
Hydrogenated fat[3]	3,250	--
Inedible fats:		
White grease (choice)	--	4,091
Yellow grease	--	4,433
Brown grease	--	4,354
Poultry grease	--	4,805
Tallow, beef	2,860	--
Tallow, No. 2	--	4,010
Hydrolyzed fat	--	3,666
	--	3,028
	3,230	--
Menhaden oil	3,700	--
Methyl esters	--	3,631
Soybean fatty acids	3,750	--
Lard " "	2,730	--
Tallow " "	2,010	--

[1] Source: Renner and Hill (1958).
[2] Source: Wilder (1959).
[3] Iodine value of 69.

Extent of Utilization of Fats

Many grades and kinds of animal and vegetable fats and oils are suitable for animal feeds. However, since fats are competing with corn on a comparative Calorie-price basis, as mentioned previously, only the cheaper grades of fats (mostly tallows and greases) are used in animal feeds. Fats and oils of grades suitable for human consumption are too costly. The quantities and grades of fats and fatty materials utilized in commercial livestock feeds in 1956 have been reported by H. O. Doty (1958), as shown in table 2.

TABLE 2.--*Utilization of fats in dry mixed animal feeds (1956)*[1]

Fatty material and grade	Amount	Ratio to total fats
Tallow:	*1,000 lb.*	*Percent*
Fancy	83,852	25.9
Prime	94,073	29.0
Other grades	58,205	17.9
Total	236,130	72.8
Grease:		
White	7,661	2.4
Yellow	41,486	12.8
Other grades	13,247	4.1
Total	62,394	19.3
Acidulated foots:		
Cottonseed	2,328	.7
Soybean	2,152	.7
Other foots	2,236	.7
Total	6,716	2.1
Miscellaneous	18,923	5.8

[1] Taken from data published by Doty (1958).

Good judgment must be exercised in the selection of fats for feeds, in order to avoid certain undesirable results. For example, if highly unsaturated fats are incorporated at high levels in the feed, problems of rancidity may develop, or the carcasses of the fed animals may be too soft and oily. Similarly, too much fish oil in the feed gives rise to odor and flavor problems; in this case, partial hydrogenation would seem to be a logical approach. Hard fats, composed chiefly of saturated acids, are less readily digested and utilized. Therefore, it may often be desirable to blend fats for feed use to approximate the range of consistency, degree of unsaturation, and fatty acid composition of the depot fats of the animal. Renderers or fat producers should also exercise judgment and care in the processing and selection of fatty materials for use in feeds. Chemically modified fats and fatty materials that have been subjected to prolonged heating at high temperatures should not be included, because of the danger of toxic substances being formed in the treatment.

ANTIOXIDANTS AND KEEPING QUALITY

When the use of fats in feeds was first proposed in 1950, the problem of oxidative rancidity was considered as a probable hurdle to be surmounted, because it was known that extensive rancidification could result not only in loss of palatability but also in loss of nutritive value and vitamins and even in possible development of antigrowth factors. The development of effective, innocuous antioxidants for preventing rancidity in fats for human edibility prepared the way, although there was no assurance they would be effective in fats in feeds. At least, they were an obvious starting point for investigation, particularly since it is desirable to stabilize the fats before and during the mixing with other feed ingredients.

Effectiveness in Fats and Feeds

The earliest report of investigations undertaken to study the stability of mixed

feeds containing added animal fats to which antioxidants had been added was that of Schweigert et al. (1952). In this report of work carried out by the American Meat Institute Foundation under contract with the U.S. Department of Agriculture, few details are given regarding the stability of feeds containing animal fats to which antioxidants had been added. It was noted, however, (1) that mixed feeds containing greases or tallows stabilized with antioxidants are not rancid after storage at room temperature for a year, (2) that a mixture of butylated hydroxyanisole (0.02 percent), citric acid (0.01 percent), and propyl gallate (0.005 percent) when added to the melted fat was equal or superior to other antioxidant combinations tested, and (3) hydrogenation of grease added to dry mixed dog food increased the stability of the fat in the feed.

A more definitive paper, published by Neumer and Dugan (1953), described the actual stabilizing value of various antioxidants when used to stabilize mixes of dry dog food with inedible grade animal fats. Samples of the feeds stabilized with different antioxidants were weighed into 4-ounce screwcap jars and stored at room temperature (26.7° C.) or in a Schall oven (63° C.). They were examined periodically for the odors characteristic of rancidity.

The more significant data obtained by these investigators at the American Meat Institute Laboratories are summarized in table 3. All the antioxidants evaluated were found to exert considerable but variable stabilizing action on the fats themselves. While measurable improvement in the stability of the feed with 10 percent of added fat was noted, the stabilizing effect of antioxidants was much less marked than in the A.O.M. tests on the bulk fat. Moreover, the antioxidants that were the most effective in stabilizing the fats did not impart more stability to the fat-meal mix than the less effective ones.

TABLE 3.--*Effectiveness of antioxidants in animal fats and dog meal-fat mixes*[1]

Antioxidant[2]	Stability of fat[3]		Stability of feed with 10% added fat[4]	
	White grease	Special tallow	White grease	Special tallow
	Hours	*Hours*	*Days*	*Days*
None (control)	10	82	23	29
BHA	48	530	--	--
BHA + CA	95	490	33	31
PG	56	808	--	--
PG + CA	64	675	27	30
p-OH-DPA	378	1,150	--	--
p-OH-DPA + CA	608	1,150	32	31

[1] Adapted from Neumer and Dugan (1953).
[2] Antioxidants added to fat in 0.01% concentration, except for citric acid--0.004%. BHA = butylated hydroxyanisole; PG = propyl gallate; p-OH-DPA = p-hydroxydiphenylamine; CA = citric acid.
[3] Peroxide value of 20 taken as rancid point in Active Oxygen Method (A.O.M.).
[4] Schall Oven Test--organoleptic rancid point (oven 63° C.).

Furthermore, rations containing added fat were always more stable than the original meal, but rations prepared with unstabilized fat added at the 6-percent level were more stable than those prepared with fat added at the 10-percent level. Most significantly the room-temperature tests were inconclusive, because all the rations tested possessed stabilities of 1 year or more.

These varied observations all point to the conclusion that natural feed materials contain substantial amounts of antioxidants essential to good stability. These natural antioxidants are probably chiefly tocopherols and similar substances known to have antioxygenic properties. It would be erroneous to conclude, however, that the addition of antioxidants to fats intended for use in feed manufacture serves no important purpose. It must be remembered that fats may be held warm for considerable periods during their addition to feeds. Moreover, the effective prevention of a buildup of peroxides by added antioxidants will certainly be worthwhile insurance against lowered nutritional value of the feed.

Methods for Incorporating Antioxidants

Once the desirability of adding antioxidants had been firmly established, attention was turned to the study of methods for their incorporation in the fat. In particular, the relative merits of adding the antioxidant to the rendering charge vs. adding it to the fat after rendering were studied.

Dugan et al. (1954) reported results of their studies when the antioxidant combination of butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and citric acid (CA) was added to the rendering charge. Such a practice, if feasible, would obviate the need for extra tanks and agitating devices usually considered essential to the incorporation of antioxidants in the rendered fats. Their studies were made in a pilot-plant unit consisting of a standard design Albright-Nell dry melter[1] reduced in size to contain 19.86 gallons. It accommodated a charge of about 100 pounds of fatty animal tissues. Fat backs which were already

[1] Mention in this publication of commercially manufactured equipment does not imply its endorsement by the U.S. Department of Agriculture over similar equipment not mentioned.

rancid were used in one series of experiments, the results of which are shown in table 4.

TABLE 4.--*Stability of fat backs rendered with antioxidant*[1]

Antioxidant[2]	Stability of grease (A.O.M.)			
	7-minute cook	1-hour cook	Final	Press
	Hours	*Hours*	*Hours*	*Hours*
None (control)	0	0	0	0
BHA	8	1	1	3
BHA + CA	16	4	5	16
BHT	34	4	4	10
BHT + CA	27	1	4	10
BHT + BHA	64	5	11	21
BHT + BHA + CA	42	7	8	27

[1] Adapted from Dugan et al. (1954).
[2] Antioxidants added before rendering in 0.01% concentration, except for citric acid (0.002%). BHA = butylated hydroxyanisole; CA = citric acid; BHT = Butylated hydroxytoluene.

All the control samples had no A.O.M. stability as would be expected with rancid fat. However, the addition of antioxidants to the rendering charge increased stability. The first sample of fat taken after 7 minutes' cooking was the most stable. This is explainable on the basis of the minimum loss of the phenolic antioxidant by steam volatilization. Since the press grease from the rendered meat scrap is second in stability, the authors suggest that as moisture is cooked out of the tissues, the fat-soluble antioxidants tend to be absorbed by the fat in the tissues. The fact that the samples of runoff fat taken after 1 hour was less stable than the final runoff fat is somewhat puzzling. Their results in commercial rendering tests confirmed the pilot-plant findings, that the inclusion of butylated hydroxyanisole in the charge before rendering increased the stability of the fat to a marked degree.

Further work has revealed that products differ greatly in their response to antioxidants whether added to the rendering charge or to the rendered fat. In some instances this variation seems to be associated at least to some degree with the content of such metals as iron. Thus, a report by Gearhart and Stuckey (1955) reveals that many fats which are difficult to stabilize can be appreciably improved by the use of higher levels of citric acid. In limited experiments with yellow-grease specimens, they found an inverse relationship between iron content and stability. In tests on the addition of the antioxidants both before and after rendering, the latter procedure was found preferable. In plant tests, extra citric acid (0.1 to 0.5 percent) added with a phenolic antioxidant increased its effectiveness when greases of low stability were encountered. Since citric acid is difficult to dissolve in fat, experiments were performed in which the citric acid was dissolved in the rendering charge. Results indicated that satisfactory stabilities could be obtained in this manner.

The principal disadvantage of stabilization during rendering is that more antioxidant will be required to achieve a given stability level or, stated another way, a given antioxidant level will give fats of lower stability. The principal advantages of stabilization during rendering are that the meat scrap as well as the fat are stabilized and, moreover, extra equipment necessary to good admixture of the antioxidant in the fat and the accompanying problems are obviated.

The amount of antioxidant to be used will vary with the stability requirements of the end products, with the type of material being rendered, and with numerous other factors. According to Dugan and Wilder (1955) most fats and meat scrap can be suitably stabilized by adding an antioxidant, such as Tenox-II (20 parts butylated hydroxyanisole + 6 parts propyl gallate + 4 parts citric acid in 70 parts propylene glycol) or Tenox-R (20 parts butylated hydroxyanisole + 20 parts citric acid in 60 parts propylene glycol) on the basis of 1 pound of antioxidant for each 4,000 pounds of fat estimated to be present in the charge to be rendered. Low grade materials or summertime rendering may require that the level of antioxidant be increased twofold and the addition of extra citric acid may be desirable.

Permissive Antioxidants

In considering antioxidants for animal feeds, it seems reasonable to assume that antioxidants permitted in edible fats for human consumption could be used. At present, Meat Inspection Regulations of the U.S. Department of Agriculture provide that, with appropriate declaration on the label, a number of preservatives may be added to rendered animal fat or a combination of such fat with vegetable fat. These preservatives and the amounts in which they may be used are as follows:

(a) Resin guaiac not to exceed 0.1 percent; or

(b) Nordihydroguaiaretic acid (NDGA) not to exceed 0.01 percent; or

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(c) Tocopherols not to exceed 0.03 percent. (A 30-percent concentration of tocopherols in vegetable oils shall be used when added as a preservative to products designated as 'lard' or as 'rendered pork fat'); or

(d) Lecithin: Provided, that nothing in this paragraph shall prevent the use of this substance as an emulsifier in an approved manner; or

(e) Butylated hydroxyanisole (a mixture of 2-tertiary-butyl-4-hydroxyanisole and 3-tertiary-butyl-4-hydroxyanisole) not to exceed 0.01 percent; or

(f) Butylated hydroxytoluene (2,6-ditertiary-butyl-paracresol) (2,6-ditertiary-butyl-4-methylphenol) not to exceed 0.01 percent; or

(g) Propyl gallate not to exceed 0.01 percent; or

(h) Combinations of two or more of the preservatives listed in subparagraphs (b), (e), (f), and (g) above not to exceed 0.02 percent; or

(i) Citric acid and/or phosphoric acid and/or monoisopropyl citrate not to exceed 0.01 percent, either alone or in combination with the preservatives listed in subparagraphs (b), (e), (f), (g) or (h) above.

(j) Recently, dodecyl (lauryl) gallate was made permissive for addition to lard that is to be exported from the United States to the Netherlands.

The use of 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline (Santoquin) is now permitted by the U.S. Food and Drug Administration (1959) in dehydrated forage crops and in poultry feed not to exceed 150 parts per million in finished feed to retard oxidative destruction of certain pigments and vitamins.

Preservation of Vitamins in Feeds

It has been noted frequently that the oxidative rancidity of fats promotes the destruction of such fat-soluble vitamins as A, D, and E, as well as some of the B-complex, thus reducing the nutritive value of the fat. Studies were carried out on the stability of the vitamin A (in fish liver oil) added to the basal rations used in the dog feeding studies and to the rations to which 6 percent of stabilized choice white grease had been added also. The results of these storage experiments were reported by Siedler and Schweigert (1954). Over a storage period of about a year the addition of 6 percent of stabilized fat to the experimental meal did not decrease the stability of the vitamin A in the meal. The retention of vitamin A through the first 18 weeks of storage was approximately 50 to 60 percent of the original vitamin A values for both meals. The vitamin A potency in the meal containing the added stabilized fat remained at this level throughout the remainder of the storage period, whereas the vitamin A values of the control meal declined to approximately 30 to 40 percent of the original values.

Bickoff et al. (1955) studied the effect of adding animal fats or vegetable oils to dehydrated alfalfa meal on the stability of carotene. Dehydrated meal mixed with 4.8 percent of tallow at a commercial dehydrator retained 62 percent of its original carotene after 16 weeks of storage as compared with 38 percent for the untreated meal. Alfalfa meal treated in the laboratory with 5 percent of highly unsaturated oils such as safflower oil retained 62 percent of the carotene after 4 months, whereas samples treated with 5 percent of more saturated fats such as cocoa butter and hydrogenated cottonseed oil retained 74 and 82 percent, respectively, as compared with 47 percent for the untreated meal. None of the fats employed were stabilized with commercial antioxidants. Dehydrated alfalfa meal is rich in tocopherol as well as other antioxidants. From the results of other experiments these workers believed that the fats and oils dissolve both the carotene and natural antioxidants, thus bringing them in contact and protecting the carotene.

Similar results were obtained by Mitchell and Silker (1955). They found that the addition of 4 percent of choice white grease resulted in the greatest improvement in carotene stability, whereas the more unsaturated salmon body oil had no effect. However, with the addition of 0.02 percent of 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline to the meal, the advantage of the white grease was eliminated.

Mitchell et al. (1954) reported that alfalfa meal containing 4 percent of cottonseed

(Wesson) oil and an antioxidant, when heated in a closed container at 100° C. for an hour, showed greatly enhanced stability on storage. Since β-carotene (pro-vitamin A) is isomerized easily by heat, thus destroying its biological value, Parrish and Mitchell (1958) considered that the photometric determination of carotene in heated, stabilized alfalfa meal might not measure the quantity of carotene available for vitamin A synthesis in the animal. However, they were able to show that the meal treated with 4 percent of cottonseed oil and 0.02 percent of 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline when heated not only yields comparable values by photometric determinations and chick growth assays, but also that the β-carotene content by chick assay was similar to that of meals, stabilized only with Wesson oil, whose initial carotene content was maintained by refrigeration. The favorable effect of heating in this case seems once again to be due to enhanced penetration of the fat into the feed particles with consequent increased contact of the carotene with the antioxidants.

The loss of carotenoids by oxidation is also a factor in the pale yolks of eggs produced by hens that have been fed rations containing 2 percent of a fish oil. This highly unsaturated oil in the absence of a stabilizing antioxidant is easily oxidized, destroying carotene in the process (Sherwood 1959).

The use of unsaturated fish oils in chick feed also produces encephalomalacia or "crazy chick" disease. Singsen (1954) has indicated that this disease is the result of a complex situation in which vitamin E deficient chicks may be fed a ration low in vitamin E and still show good growth and low mortality. However, the addition of 1 to 2 percent of a fish oil, such as menhaden oil, results in high mortality. Normal chick rations usually contain approximately 3 International Units (I.U.) of vitamin E (α-tocopherol) per pound. A poultry ration containing 2 percent of fish oil plus 7-11 I.U. of vitamin E may be safely fed.

In a series of experiments in which chicks were injected intramuscularly with vitamin E solution, Singsen found that injections in amounts equivalent to that consumed in the diet by chicks of the same age gave complete protection against disease. He concludes from these and other experiments that the protective action of vitamin E takes place in the body rather than in the ration.

Singsen was able to prevent encephalomalacia through the use of 0.0125 percent of the antioxidant, N,N-diphenyl-p-phenylenediamine, in the diet or by injecting similar quantities intramuscularly in place of vitamin E. The use of this antioxidant at levels amounting to 0.0125 percent of the final feed mixture to stabilize the fat or oil materially increases the cost of the oil and is far in excess of the amounts required of other antioxidants discussed in the previous section on fat stability. Moreover, this antioxidant is no longer approved for general use in feed. While it is one of the most successful materials in "substituting for vitamin E", such compounds, as pointed out by Gitler et al. (1958), correct only certain symptoms of vitamin E deficiency, whereas tocopherol corrects all of them. It apparently is ineffective in substituting for vitamin E in the reproductive process such as the prevention of resorption in rats and may even result in deleterious effects on the gestation of rats. (Ames et al. 1956; Oser and Oser 1956).

STORAGE, HANDLING, AND MIXING OF FATS IN FEEDS

Equipment and Storage

The two most important factors adversely affecting the stability of fats are air and water. Water also leads to hydrolysis of the fat, with a consequent increase in free fatty acids. Rose (1956) indicated that free water present in a fat will effectively extract the citric acid and reduce the efficiency of the antioxidant accordingly. Clean, dry fat stored at ordinary temperatures in clean tanks will keep very well.

Fats to be mixed into feeds will be received from the producer in tank car, tank truck, or in drums, depending upon the rate of usage and upon the storage and handling facilities available to the feed mixer. If delivered by tank car or truck, storage facilities must generally be provided.

Storage tanks may be either horizontal or vertical. Second-hand tanks, such as those from tank cars are sometimes used. All tanks should be provided with a free-vent

at the top, with the vent end of the pipe turned down for weather protection. The available storage capacity must be determined by the rate of usage and availability of supply. Unnecessarily large storage is not only expensive but undesirable, and two smaller tanks are better than one large one. When two tanks are available, failure of a steam coil or other similar problem will not stop the fat-handling operation; tank repair and cleaning will also be facilitated without interfering with production. Storage tanks should be completely emptied occasionally for cleaning. The oldest stocks on hand should be used first, since fats, like other foods, do not improve with storage.

It is best to store fat at as low a temperature as possible in order to keep it in optimum condition. If large amounts are to be used each day, the fat in storage may be kept at about 15° above the melting point, or at about 120° F. In the summer months, fat at this temperature will be warm enough to mix into feed, but in the winter months it should be kept at a higher temperature. Insulating the storage tank will greatly aid in maintaining the required temperature and will reduce the amount of heating required.

Tallows and grease have melting points between 100° and 110° F. and in the colder months of the year may be quite hard when delivered. If shipped in tank cars, use of steam will usually be necessary to melt the fat before pumping to storage. Wilder (1954) stated that usually 180 feet of 1-1/2 inch pipe heated with steam at 80 pounds' pressure will be required to melt and heat 60,000 pounds of fat from 0° to 140° F. in 10 to 12 hours. He estimated that a boiler having a capacity of about 11 to 15 horsepower could supply the necessary steam. In warmer weather, a lesser amount of steam is required, and once melted, only a small amount is required to maintain the fat in a liquid condition.

A heating device must also be installed in the storage tank. If a horizontal tank is used for storage, it must be set level so that the coils will drain to prevent freezeup in cold weather. In all tanks, a steam coil loop should be run up to a point above the top level of the fat or the steam pipe may be led into the tank at the top and down near one side to the heating coil at the bottom. This loop will melt a channel of fat which will permit circulation of liquid fat and prevent high pressure buildup at the bottom under a solid surface. When heating is stopped, it is good practice to disconnect the heating coil and blow out any condensate with compressed air. The coils should be left disconnected until again needed.

If steam is not available in the plant or if the fat is received in drums, it may be more convenient to use electric heaters to melt the fat. An electric immersion-type heater or a drum heater may be used. Wherever electric heaters are used, they should be thermostatically controlled and installed in such a way that there is no localized over-heating in any part of the heater that is not covered by fat. Fats are flammable and will burn if brought into contact with an overheated electric heating element. When properly installed, electric heaters are safe and convenient.

Waibel et al. (1958) reported the results of their work on a comparison of various methods of heating 55-gallon drums of animal fat prior to incorporation into feeds. Two types of electric heating units were tested, immersion and outside. An immersion heater melted all the fat in a relatively short time and tended to mix the hot fat well. However, it was difficult to insert in cold-weather tests. Outside drum heaters were simple and efficient to use but left an unmelted cone during cold weather.

In some plants it may be necessary to have long pipe lines to the storage tank or from storage to mixing area. A steam or electric tracer line may be installed on the underside of the fat line and the twin lines covered with pipe insulation. A 3/8-inch copper pipe may be used as a steam tracer for heating the fat lines or an electric heating tape or cable may be used. If an electric heater is used, it should be thermostatically controlled to prevent overheating. Steam tracer lines should be installed with all offsets around flanges, valves or other fittings in a horizontal plane to avoid freezing in low pockets in which condensate might collect. It is advisable to blow out lines when not in use to prevent accumulation of moisture.

Brass, bronze, monel, or any alloy containing copper should be avoided in piping, valves, fittings, and pumps, because dissolved copper tends to promote a reaction between oxygen of the air and the fat to produce undesirable oxidative rancidity. The use of rubber in joints, gaskets, and hose with which the fats may be in contact is also to be avoided. All flanged joints in piping should be made up with asbestos, neoprene, or stainless-steel gaskets. Suction hoses for unloading tank cars or trucks or for flexible piping uses should be made

of neoprene or at least be neoprene lined.

Liquid fat is easy to pump and most types of pumps can be used. If lines are short and the fat always warm, a low-pressure rotary pump may be sufficient. On the other hand, cool fat is rather difficult to pump unless the right type of pump is used. Experience has shown that a gear type of pump is probably the most satisfactory. Gear pumps should be equipped with pressure relief valves so as to guard against motor overloading in the event they pump against a closed line. To avoid interruptions during maintenance or pump failure, it is often advisable to have pumps in duplicate.

Producers of tallow and grease are well aware of the factors to be considered in laying out the necessary piping for moving fats. Feed plants considering installations for handling fats from storage to mixers might do well to consult with the nearest fat supplier as to layout, pipe sizes, pumps, and fittings.

Mixing Fat into Feeds

Problems involved in the actual mixing of fats into feeds have been discussed in several places (American Meat Institute 1953; Horton 1956; Norton 1956; and Walter 1958). The actual mechanics of adding fat to feeds do not present any major problems. Methods and equipment to be utilized will be determined by the specific production and mechanical requirements of the individual feed plant.

Tallows, greases, and most other fats must be heated to make them sufficiently liquid to flow through the piping to the mixer and to get a good coating of fat on all feed particles. Warm fats will be easier to mix into feeds than almost any other type of liquid material, because it is readily absorbed by most other feed ingredients. In plants where only moderate amounts of fat are used each day, it may be convenient to pump the fat from storage to a preheating tank in which the temperature is thermostatically controlled at the most desirable temperature--usually somewhere between 120° and 160° F. The temperature will depend on that of the mixing room and of the feed ingredients, the type of mixer used, and the degree of agitation obtained in the mixer.

Either steam coils or electric heaters may be used. Heaters located in the bottom of the tank are safe, provided the level of the fat does not get below the heating surface. A fat-level indicator or level control device will be helpful. Provision should be made to stir the fat in the preheater tank. This applies to the storage tank as well, if the storage tank is kept at higher temperatures in lieu of using a preheater in front of the feed mixer. Most tallows and greases contain a small percentage of moisture and insoluble matter which, if not kept stirred up, will settle out and eventually accumulate at the bottom. Insoluble matter may have a tendency to sour if allowed to accumulate in the tanks. Adequate stirring by mechanical stirrer or air agitation will prevent major accumulation of sludge in the tank and obviate the necessity for frequent cleaning of the tank bottom. An alternative is careful drying and filtration of the fat by the user.

The heated fat should be conveyed to the mixer by the shortest and most convenient route. If the storage and heating tank can be located above the mixer, the fat will flow by gravity. Combination equipment is available that will provide a preheating tank, pump, and measuring equipment in a single unit for attachment to the feed mixer. Similar combinations also may be obtained that are equipped with several pumps and thus are capable of supplying fat to several mixers simultaneously.

The amount of fat going into the mixer may be measured by any means suited to existing equipment. In batch-type mixers, any system may be used from the simplest--such as the use of calibrated markings on the side of a tank--to the most elaborate, completely automatic systems. In some cases, a meter, such as a water meter, has been useful for measuring the number of gallons of fat run into the mixer. In other cases, proportioning pumps have been used to deliver a definite amount in a given time. For continuous mixers or automatic operation of batch mixers, flow-meter equipment is available that will control the fat used at any predetermined amount. Flow meters can also be obtained for any desired degree of automatic operation from simple, manually operated to completely automatic units.

Almost any existing type of feed mixer can be used to put fat into feeds. Many mills have already converted horizontal, vertical, or continuous mixers to handle fats. Frequently, other equipment may already be on hand for handling other liquids and may be found adaptable to handling fat.

Horizontal mixers may do their best job if the fat is sprayed into the feed in the

mixer. Vertical mixers, on the other hand, are easily adapted to mixing fats by merely pouring the fat into the loading hopper after most of the other feed ingredients have been loaded. No spray is needed in the vertical mixer. The fat-delivery pipe is outside the mixer in full view, so that the rate of delivery can be observed. With some vertical mixers it is advisable to increase the speed of the elevating screws to insure against the formation of feed balls with the fat, but this is best determined by experience.

Pelleting feeds containing added fat sometimes requires a change in technique. Feeds can be pelleted with fat added at levels up to about 3 percent and a good hard pellet has been produced with fat added as high as 5 percent. Above this level and even in the range of 3 to 5 percent, difficulty is often experienced in getting a good hard pellet that will withstand handling. To overcome this problem many methods have been tried. They include an increase of die thickness, use of additives to act as binders or to absorb the fat, and altering the preparation so as to increase the rate of absorption of the fat by other ingredients. At present, considerable attention is being given to the addition of at least a part of the fat after pelleting. Adding a small amount of fat (about 1 percent) previous to pelleting will, in such cases, increase production without lowering the pellet quality. Die and roller life of the pellet mill will also be increased. The remaining amount of fat can be added to the pellets. Hard feed pellets will absorb more than 3 percent of fat without breaking. In fact, one manufacturer reports development of a system for adding up to 10 percent of fat to pellets.

Opinion remains divided regarding the best treatment after the fat is sprayed onto the pellets. Some advocate binning or sacking the pellets after coating them with fat. This operation is simple and the cost low. Others propose that pellets, after being coated, should go to a dryer to raise the temperature and thereby promote a rapid and more thorough absorption of the fat. The pellets must then be cooled. It is reported that the addition of fat to pellets results in a cost slightly greater than that of adding fat to the meal before pelleting, but the greater resulting flexibility permits the feed manufacturer to take advantage of the market availability and fluctuating prices of different fats.

ANIMAL FEEDING WITH FAT-SUPPLEMENTED FEEDS

POULTRY

Poultry rations were selected for early investigation by the American Meat Institute in cooperation with the U.S. Department of Agriculture primarily because they offered the greatest potential outlet for fats. In recent years over 30 million tons of such feeds have been produced annually. The addition of even 2 percent of fat to all poultry feeds would require 1.2 billion pounds or more than one-third of our total inedible fat production.

In current commercial practice as much as 6 percent of fat is used in poultry feed, but the average is closer to 2.5 percent (MacGregor 1956), partly because feeds containing more than 3 percent of added fat are difficult to pellet. Furthermore, the amount of fat that can be added conveniently to mashes also is restricted by mechanical problems in mixing and handling.

The early use of fats in poultry feeds was limited by the lack of knowledge of the requirements of poultry for other nutrients in the diet during growth and maturity. Early investigations indicated that the addition of a moderate amount of fat improved feed efficiency. The use of larger amounts resulted in little further increase in feed efficiency and in some experiments seemed to inhibit the growth of young birds and cause metabolic malfunctioning. More recently, the use of 30 or even 50 percent of fat in experimental chick rations, properly balanced with respect to minerals, vitamins, and particularly amino acids and protein, has resulted in striking increases in feed efficiency and in rates of growth comparable to those obtained with modern, properly balanced, practical-type rations. Knowledge of the proper balance of nutrients for the effective use of fats in turkey poult rations is still incomplete and is largely lacking for young ducks and geese.

The use of fat in poultry rations in recent years has been limited by the higher price of various grades of inedible fats. As a

result, there has been increasing competition from grains as sources of energy, particularly in feeds for mature birds where the energy requirements are moderate and the effectiveness of fat is marginal.

Chickens

Broilers:--Early investigations on the feeding of rations containing added fat to chicks gave conflicting and inconclusive results concerning the amount and kinds of fat that could be used advantageously. These results were due probably to incomplete knowledge of poultry nutrition and the failure to maintain a proper balance of fats with other food elements, particularly proteins. Henderson and Irwin (1940) found that chicks tolerated as much as 10 percent of soybean oil in their ration, but higher levels caused growth depression and excessive shedding of feathers. On the other hand, Reiser and Pearson (1949) fed 20 percent of lard in a purified diet to chicks without harmful effects, whereas 20 percent of cottonseed oil in the ration resulted in poor growth particularly in riboflavin-deficient diets. Yacowitz (1953) found that 2.5 to 5 percent of cottonseed oil, soybean oil, or lard improved growth and feed efficiency of growing chicks, whereas 15 percent of cottonseed oil resulted in depressed growth and poor feathering.

In more practical experiments, Schweigert et al. (1952) conducted a systematic study of the effects of feeding chicks commercial-type rations to which were added 2, 4, and 8 percent of the less expensive, stabilized, inedible fats (tallow and grease). As shown in table 5 male chicks made greater growth gains on the fat-supplemented feeds than did the female chicks.

TABLE 5.--*Gain and feed utilization of chicks fed graded levels of fat*[1]

Supplements to basal ration of--	Weight of chicks at 9 weeks		Feed efficiency[2]	Caloric efficiency[3]
	Males	Females		
New Hampshire chicks:	*Grams*	*Grams*	*Feed/gain*	
None..................	1,335	1,171	2.63	10.8
Fat:				
2 percent...........	1,322	1,115	2.63	10.4
4 percent...........	1,414	1,047	2.56	10.4
8 percent...........	1,409	1,107	2.56	9.9
White Rock chicks:				
None..................	1,269	1,114	2.56	11.1
Fat:				
2 percent...........	1,390	1,160	2.50	11.0
4 percent...........	1,405	1,067	2.50	10.6
8 percent...........	1,374	1,172	2.33	10.9

[1] Schweigert et al. (1952).
[2] Pounds of feed consumed per pound gained.
[3] Grams gained per 100 Calories consumed.

Slightly increased feed efficiency was noted for chicks on fat-supplemented feeds, an indication that the added calories (fat) were well utilized. The protein level of the basal diet was 23 percent. Sunde (1954) substantiated these results in general and extended the observations to turkey poults.

At about this time, the importance of protein levels of the diets in connection with fat supplementation began to receive greater attention. Biely and March (1954) found that fat added to a diet containing only 19 percent of protein depressed growth and feed efficiency, but when added to diets containing 24 or 28 percent of protein the fat increased feed efficiency without adverse effect on growth. These findings were confirmed by other workers, who further emphasized the importance of a proper balance between total Calories and protein level in the diet. Combs and Romoser (1955) were the first to advocate the use of the optimum Calorie-protein ratio as a guide in the practical formulation of poultry feeds. Simply defined, the Calorie-protein (C/P) ratio is the Calories of productive energy per pound divided by the percentage of protein in the ration. According to Wilgus (1957) the factors which affect the C/P ratio are the quality of protein, amount and quality of added fat, rate of growth, desired finish, rate of egg production, temperature, exercise, body size, and sex.

The productive-energy values used most generally in calculating the Calorie content of a poultry feedstuff are taken from tables published by Fraps (1946). They are based on the net energy derived from the feed and stored as fat and protein in the growing chicken. Titus (1955) has offered a number of valid criticisms of Fraps values; however, the use of these values in formulating diets aimed at optimum C/P ratios has proved to be a useful practical tool. Titus (1955a) published a table of corrected productive energy values and also a table of estimated metabolizable energy values. Metabolizable energy is the total energy of a feedstuff as determined by complete combustion less the sum of the total energies of the material excreted in the feces and urine and, as such, is a measure of the energy available for all metabolic processes including production of body heat and maintenance. Although more accurate and experimentally reproducible than productive energy, directly determined values are not generally available.

Donaldson et al. (1957) in a series of carefully planned experiments showed that

the addition of as much as 30 percent of stabilized yellow grease to a ration already containing 3.8 percent of fat did not depress growth. This ration was a carefully formulated practical type containing adequate amounts of all known nutrients and supplemented by materials containing unidentified growth factors. In one experiment involving the feeding of eight practical type rations to which had been added 10 percent of stabilized yellow grease, chicks at the end of 4 weeks were markedly superior in growth and feed efficiency to chicks fed on the basal ration containing no added fat. In their experiments the C/P ratio ranged from 40.0 to 48.2. They emphasized that "for the satisfactory use of high fat levels, the ration must be properly balanced especially in respect to protein (amino acids) in relation to energy content."

In further studies on high efficiency broiler rations, Combs, Quillan, et al. (1958) found that one group of chicks on a high efficiency semipurified diet reached a 3-pound average weight in 50 days with the feed conversion of 1.04 pounds of feed per pound of bird. The semipurified diet fed for the first 4 weeks contained 1,722 Calories per pound, 41.3 percent of protein, and 38.6 percent of fat. This diet was followed by one containing 1,959 Calories per pound, 33 percent of protein, and 50.9 percent of fat. These rations contained ingredients not suitable for practical use.

However, they obtained excellent results with rations composed of practical ingredients, feed conversions of 1.19 to 1.37 pounds of feed per pound of bird being obtained. One of these groups reached a 3-pound average weight on the 46th day. In these rations the added fat consisted of a mixture of corn oil and tallow; the total fat in the diet ranged from 33.8 to 35.5 percent, depending on age. The feed conversion on a modern 1958 low-fat commercial feed ranged from 1.79 to 1.98 pounds of feed per pound of bird. However, the rate of growth on this modern feed was very good, a 3-pound bird requiring from 49 to 54 days of growth. In extreme contrast were chicks fed on a modified 1912 diet which required 3.03 pounds of feed per pound of bird and 11 weeks to produce a 3-pound bird. These figures illustrate the tremendous changes that have taken place in modern poultry nutrition.

Biely and March (1957) extended their investigation of the relationship between fat and protein content in the diet. Using a fully supplemented practical type diet, they carried out three experiments in which groups of 24 or 25 New Hampshire cockerels were fed diets containing from 18 to 33 percent of protein. Each protein level was fed with several levels of dietary fat (and of productive energy). The effect of adding 12 percent of tallow or 12 percent of corn oil to diets containing 22 and 33 percent of protein are shown in table 6.

TABLE 6.--*Fat and protein efficiency, young chicks*[1]

Protein, percent	Fat[2]	Energy (productive)	Calorie-protein ratio	Av. weight of chicks at 4 weeks	Feed efficiency	Nitrogen retention	Fat retention	Fat digestibility
		Cal./lb.	*C/P*	*Grams*	*Feed/gain*	*Percent*	*Percent*	*Percent*
21.6.........	--	925	42.8	344	2.42	47.1	58.6	--
22.5.........	Tallow	1,135	50.4	376	1.90	57.2	77.4	80.4
22.5.........	Corn Oil	1,135	50.4	334	2.15	55.3	90.7	95.8
33.1.........	--	865	26.1	348	2.29	41.0	60.5	--
33.4.........	Tallow	1,090	32.6	414	1.64	48.6	83.0	86.9
33.4.........	Corn Oil	1,090	32.6	426	1.60	52.6	92.2	97.6

[1] Adapted from Biely and March (1957).
[2] The tallow and corn oil were added at the 12 percent level.

Adding tallow to either the 22- or 33-percent protein diets accelerated growth and improved the efficiency of feed utilization, particularly at the higher level. Corn oil was without effect on growth when added to the 22-percent protein diet but improved feed efficiency. With the 33-percent protein diet, the rate of growth and the efficiency of feed utilization were similar with either the 12-percent tallow

or the 12-percent corn oil. The efficient use of protein (i.e. nitrogen retention) was improved with the addition of fat, and retention and digestibility of the fat was improved at the higher protein level.

The problem of fat retention and digestibility has been investigated by other workers. Duckworth et al. (1950) found that chicks, like other animals, show a difference in the digestibility between high- and low-melting fats. Sunde (1956) concluded that the chick does not utilize saturated long-chain fatty acids. Carver et al. (1955a) reported that "neither hydrogenated tallow or hydrogenated tallow fatty acids are efficiently utilized as fat supplements to broiler feed."

March and Biely (1957) investigated the utilization by New Hampshire male chicks (fed 4 or 6 weeks) of beef tallow, hydrogenated animal fat (HAF), and corn oil when added to a practical-type diet containing 25 percent of protein. The addition of HAF to the basal diet stimulated growth at the 3-percent level but depressed growth at the 12-percent level. HAF did not affect feed efficiency, although it was poorly utilized. Beef tallow at the 12-percent level improved feed efficiency but did not stimulate gains in weight. Corn oil improved feed efficiency at all levels (3 to 12 percent) and stimulated growth at the 3-, 6-, and 9-percent levels. The coefficients of digestibility for corn oil, beef tallow, and HAF were 90, 73, and 44 (or 23) percent, respectively. These values are not as high as those reported in the literature, because fatty acids excreted as soaps were taken into account in these experiments. The addition of 0.5 percent of lecithin or 0.1 percent of Santomerse-80 did not affect the utilization of the fats but seemed to affect the form in which the fat was excreted. In general, chicks fed hydrogenated animal fats excreted a higher proportion of fat as triglycerides.

However, Combs, Helbacka, et al. (1958) found little difference in weight or feed efficiency when 2 or 10 percent of tallow, yellow grease, vegetable fat (Drew NRG-50), or hydrolyzed animal and vegetable fat was fed to cross-bred chicks (Vantress X Arbor Acre) in a fully supplemented practical diet for 8 weeks.

Baldini and Rosenberg (1957) conducted some experiments designed to determine whether the beneficial effects of fat are due entirely to its energy content or to some other intrinsic value of fat. A supplemented practical diet was fed to battery-reared New Hampshire male chicks in 3 or 6 replicate groups of 16 chicks. The diet contained enough fat to meet the chicks' requirement for essential fatty acids and an adequate protein content. The authors showed that the same number of Calories supplied either as fat or carbohydrate gave identical gains in weight and feed efficiency, and that the weight of feed consumed per bird was essentially identical. They also showed that the body composition of the chicks was substantially identical as to moisture, protein, fat, and ash content. They concluded that in a diet adequately supplied with essential fatty acids, the effect of fat is due entirely to its caloric value.

Results of a number of recent investigations have caused this conclusion to be questioned. Denton and Menge (1959) have shown that egg yolk oil has a definite effect on the growth of chicks beyond that expected from the caloric content of the diet. Similar results have been obtained by Carew et al. (1959) with soybean oil and Scott et al. (1958) with corn oil. Research to date has not shown conclusively whether this is due to a specific metabolic effect of the fat per se or to the presence of unidentified growth promotant factors in these oils.

Carcass quality of the edible broiler-fryer is of great concern to poultry producers, processors, and consumers and is the ultimate test of the value of a particular broiler ration. Fortunately, the addition of stabilized fat to broiler rations results in equal or possibly better carcass quality than that obtained with low-fat diets. Schweigert et al. (1952) reported that 10 representative broilers fed a basal practical diet and 10 fed the basal diet plus 8 percent of stabilized white grease were dressed at a poultry processing plant and evaluated for pigmentation, finish, and dressing percentages. Both groups were judged excellent and not significantly different.

Combs, Helbacka, et al. (1958), using a carefully formulated and supplemented basal diet, compared the effect on carcass quality of adding hydrolyzed animal and vegetable fat, vegetable fat, tallow, or yellow grease at levels of either 2 or 10 percent. All rations yielded birds with good quality carcasses. Pigmentation and finish were excellent, and dressing percentages were essentially the same in all groups with the exception that the group receiving 10 percent of hydrolyzed fat had a higher dressing percentage. This

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group also had the highest numerical abdominal fat score. Both observations suggested a higher fat content of the carcass.

In other studies Combs, Quillin, et al. (1958) compared the carcass quality of broilers when they reached a live weight of 3 pounds. One group (as described previously) was fed on a high-fiber, low-energy 1912 diet; the other groups received a variety of modern poultry diets, including a low-fat commercial diet and high efficiency (high-fat) practical and semipurified diets. The percentage of edible carcass remaining after dressing and evisceration was essentially the same on all diets, with the exception that the gizzard weights of broilers fed the 1912 diet were approximately double those fed the various 1958 diets. On the other hand, those groups fed rations extremely high in fat had heavier livers. The carcass quality and shape of the broilers fed the modified 1912 diet were strikingly different. They were, of course, older at the 3-pound weight (78 days vs. 45 to 55 days for groups on 1958 diets), but their carcasses were much longer and less well finished with prominent breasts. Their body shape was triangular, while those fed the 1958 rations approached more nearly a rectangular shape. They also had a much larger body cavity which before killing gave them the appearance of weighing 50 percent more than those fed the 1958 rations, even though they actually weighed the same.

The stability of the carcass fat of broilers is also a matter of concern in the marketing of these birds. Schweigert and Siedler (1954) reported that the fatty acid composition of the depot fats of broilers receiving a basal ration supplemented with 8 percent of animal fat contained considerably less linoleic acid and more oleic acid, with consequent lowering of iodine number as compared with the depot fat of birds on a straight basal ration. In a later paper Siedler et al. (1957) reported on an experiment in which groups of broilers were fed rations consisting of basal feeds supplemented with either no animal fat, 6 percent of unstabilized animal fat, 6 percent of animal fat stabilized with 0.02 percent of Santoquin (1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline); 0.02 percent of BHT (2,6-di-tertiary-butyl-p-cresol.); or 0.02 percent of DPPD (diphenyl-p-phenylenediamine). Citric acid was added at a level of 0.01 percent to all antioxidant-treated fat. This fat consisted of a blend of choice white grease and choice tallow. The A.O.M. stability on depot fats of the various groups of broilers ranged from 2 to 5 hours for birds on diets containing no added fat to 10 hours for several groups receiving stabilized or unstabilized animal fat. However, this effect was not consistent for all groups. Therefore, they concluded that there was little or no increase in stability when either stabilized or unstabilized animal fat was added to the diet at the level tested. They also noted that there was no significant difference in flavor between any of the groups tested, but that the birds receiving rations with added fat had twice as much depot fat.

The palatibility of broilers that had been fed fish oil or tallow was investigated by Carlson et al. (1957). The evaluation was carried out by a large consumer-type panel and also by a trained group. Both found that cooked meat of broilers fed more than 0.5 percent of menhaden oil in their diet had objectionable off-flavors. This was not corrected by adding 0.0125 percent of DPPD to the rations of birds fed menhaden oil diets. Broilers that had received tallow in their diet (maximum of 2 percent) were favored. The trained group scored the meat of these birds higher on full chicken flavor, while the consumer panel found a combination of flavor and tenderness which they preferred.

Harms et al. (1957, 1957a) investigated the losses in weight in both the dressing and the cooking of broilers. They found that broilers receiving diets containing increasing amounts of stabilized yellow grease (maximum of 6.3 percent) gave higher eviscerated carcass yields. On cooking, the carcass of broilers fed 6.3 percent of fat in their diet had a higher percentage of drippings but a lower loss of moisture in cooking. As a result, the total cooking loss was lower.

Laying hens:--Research has demonstrated clearly the value of adding fat to the diet of laying hens for increased feed efficiency in egg production. As yet, however, results are inconclusive as to the energy requirements for maximum rate of egg production and as to many other problems associated with the reproductive processes in the chicken. The problem is complicated by considerations of desirable growth-rate of the pullet replacement for the laying flock, productive lifespan, wide variations in the genetic background of various strains, environment, production of breeding stock, and interrelationships with other nutrients in the diet.

According to Heuser et al. (1945) feeds low in fiber and high in energy supported better egg production in White Leghorns than feeds high in fiber and low in energy. At about the same time, Bird and Whitson (1946) reported increased efficiency for Rhode Island Red hens on diets low in fiber and high in energy. However, these workers concluded that egg production was approximately as good on high-fiber, low-energy rations. Lillie et al. (1952), also using Rhode Island Reds, found that the addition of 8 percent of lard to the rations of these birds produced greater body-weight gains and improved feed efficiency but did not increase egg production.

Singsen et al. (1952), using Barred Plymouth Rocks and Rhode Island Reds, and Gerry (1954) reported higher efficiency, measured as feed requirements per dozen eggs produced on high-energy rations. In four out of five experiments, Singsen et al. obtained greater egg production on high-energy rations. However, Gerry reported that egg production was similar on high- or low-energy rations.

Hill et al. (1956) described a careful study of the effect of dietary energy level on the rate and gross efficiency of egg production. They conducted two experiments in central New York with April-hatched Single Comb White Leghorn pullets. In the first experiment the three rations employed each contained approximately 17.5 percent of protein and were formulated from common feed stuffs supplemented by vitamins and minerals. The high-energy ration, with corn and wheat being the only grain components, was estimated to contain approximately 930 Calories of productive energy per pound. This ration was modified to form the medium-energy and the low-energy rations, containing 840 and 740 Calories per pound, respectively, by replacing wheat and part of the corn with wheat byproducts, oats, and alfalfa meal. The hens were fed the experimental rations from mid-September 1951 until the following August 18, 1952. The effect of the three rations on egg production, calculated by months on a hen-day basis, is shown graphically in figure 1. It is evident from the figure that energy level had little effect on production during the fall (September - November) and spring and summer (May - August). During winter, however, consistently greater production was obtained with the high-energy ration.

A summary of average egg production, feed consumption, and gross efficiency of

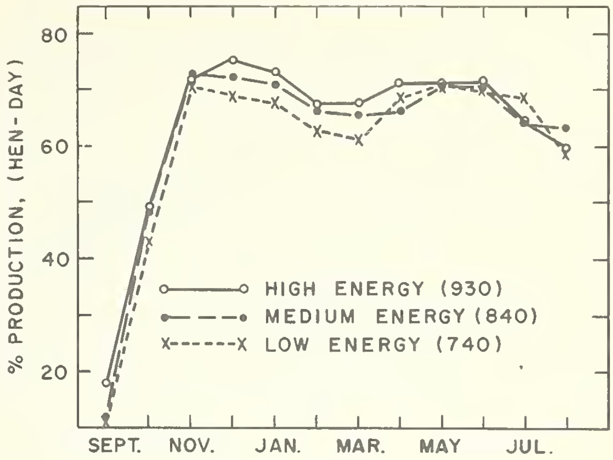

Figure 1.--Effect of dietary energy level on the monthly rate of egg production.

production is shown in table 7 for the period October 1 to August 18. In spite of the somewhat higher rate of egg production obtained with the high-energy ration, the rate of feed consumption was substantially less with this ration than with the other two. The gross efficiency of egg production was therefore markedly superior with the high-energy ration--approximately 20 percent less feed was required per dozen eggs.

TABLE 7.--*Effect of energy level of ration on the rate of egg production and feed consumption*[1]

Ration	Energy (productive)	Rate of egg production[2]	Daily feed per 100 hens	Feed per dozen eggs
	Cal./lb.	*Percent*	*Pounds*	*Pounds*
High energy.........	930	68.1	26.1	4.60
Medium energy.......	840	66.9	28.9	5.19
Low energy..........	740	64.9	31.0	5.74

[1] Adapted from Hill et al. (1956).
[2] Experimental period October 1 through August 18.

The second experiment was conducted to investigate a higher range of energy levels through the use of a feed-grade tallow stabilized with an antioxidant. The basal ration for this experiment was similar to the high-energy ration of the previous one, except that it contained 16 to 16.5 percent of protein and a higher level of calcium. The tallow was incorporated in two rations at levels of 2.5 and 5 percent. The productive-energy values of the rations ranged from 945 to 1,025 Calories per pound, with a value of 2,900 Calories per pound of tallow. The rations were fed from October 20, 1953, to August 31, 1954. The monthly percentage rate of egg production is shown

graphically in figure 2. Again, production was markedly better only in the winter months, particularly in February and March.

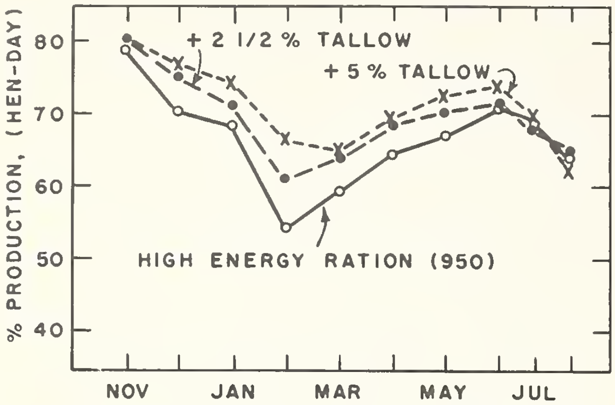

Figure 2.--Effect of added tallow on the monthly rate of egg production.

Data showing the average egg production, feed consumption, and feed requirements per dozen eggs for the 10-month period, November through August, are presented in table 8. The higher the energy content of the ration, the higher the average rate of egg production and the lower the feed consumption and feed requirement per dozen eggs. The efficiency of the high-energy basal ration was approximately the same as that observed for the similar ration in the first experiment and was improved approximately 10 percent by supplementation with 5 percent of tallow.

TABLE 8.--*Effect of increasing energy level with added tallow on the rate and efficiency of egg production*[1]

Level of added tallow, percent	Energy (productive)	Rate of egg production[2]	Daily feed per 100 hens	Feed per dozen eggs
	Cal./lb.	*Percent*	*Pounds*	*Pounds*
0	945	66.5	25.6	4.62
2.5	985	69.5	25.2	4.35
5.0	1,025	70.9	24.6	4.16

[1] Adapted from Hill et al. (1956).
[2] Experimental period November through August.

From data obtained in these two experiments it is evident that under the climatic conditions of central New York State, egg production is influenced by the dietary energy level only during the cold weather months. However, as Hill (1956) was able to show by means of the Byerly (1941) partition equation, the data in these experiments demonstrated that the relation between energy level and relative efficiency is linear and that improvement in feed efficiency is approximately proportional to the increase in dietary energy.

Harms et al. (1957) obtained increased egg production and increased feed efficiency on higher energy diets fed to White Plymouth Rock, New Hampshire, and White Leghorn pullets. In contrast with Hill, they found this difference to exist throughout the year, although there was a tendency for the difference in production of the two groups to narrow with the onset of warm weather. More recently, Hochreich, Douglas, and Harms (1958), adding 6.6 percent of stabilized yellow grease to a diet containing 950 Calories of productive energy per pound, found the additional Calories did not increase the rate of egg production but did significantly improve feed efficiency of Single Comb White Leghorn pullets. These latter experiments were designed to give careful consideration to the optimum relation between protein and energy requirements. They found that a level of 17 percent protein in a feed containing 950 Calories per pound was required to maintain maximum egg production and feed efficiency; the addition of 6.6 percent of fat required 18.35 percent of protein in the diet--a C/P ratio of 56:1. When the protein level was lower than these values, the rate of egg production decreased.

Other groups have studied the interrelationship between energy and protein requirements with considerable variation in results. This work has been reviewed in some detail by Waibel (1959). He states: "In all the studies cited, there are only two satisfying the qualifications of 70-percent production for 200 days or 60-percent production for 300 days and enough groups to establish the suboptimum egg production and a plateau of performance. These are the reports of Hill and Anderson (1955) and Hochreich et al. (1958). Here in six comparisons the average optimum Calories to protein ratio was 60. This is equivalent to 15 percent of protein for a 900 Calorie-per-pound ration."

A number of groups report good egg production with rations containing as little as 12.5 percent of protein. Miller et al. (1957), in feeding Single Comb White Leghorn pullets in laying batteries with raised wire floors, obtained good egg production with rations containing 12.5 to 13 percent of protein and a C/P ratio ranging from 31:1 to 86:1. However, in order to realize the full feed efficiency of adding up to 10 percent of stabilized white grease (resulting in rations containing as much as 1,075 Calories per pound), it was necessary to have protein levels at 19.2 to 20.9 percent.

Of course, all proteins are not equal in nutrient value. Fisher and Johnson (1958) obtained good egg production and general performance with a ration containing 10.4 percent of protein, in which the amino acid content was similar to that developed by them in previous studies of free amino acid diets. In this same study, an 11.3-percent protein ration gave poor results, suggesting an amino acid imbalance. This result emphasizes the fact that the closer a feed approaches the lower limit of protein requirement, the more necessary it will be to specify the amino acid content rather than total protein.

Assuming that a diet contains the required protein (and amino acid) content, it becomes necessary to consider what energy levels may be used advantageously. Again as noted by Waibel (1959), Hill and Anderson (1955) found that the use of 5 percent of yellow grease at 15-, 16-1/2- and 18-percent protein levels (960 PE Calories/pound basal diet) resulted in greater egg production. Data of McDaniel et al. (1957) showed that at 18-percent protein levels, added energy from poultry oil (1,050 vs. 962 PE Calories/pound) gave slightly higher production with Hyline and DeKalb stocks but not with White Leghorns. Miller et al. (1957) observed that the amount of energy, ranging from 640 to 1,075 Calories per pound at various protein levels, did not have any influence on egg production. The work of MacIntyre and Aitken (1957) indicated that production was as good at 720 Calories per pound of ration as at 900 Calories per pound. Thus, it becomes evident that, except in such cases as cold weather feeding and in the feeding of certain breeds of laying hens where fat is particularly advantageous in maintaining high egg production, fat must compete with grains and other energy sources. This then becomes a problem of economics and the cost of a unit of energy derived from industrial-feed grades of fat as compared with that of other energy sources.

In recent years, there has been increased interest in restricted feeding both of the immature replacement pullet and the laying hens. This is due, in part, to the tendency of the heavier breeds (especially broiler types) to become overweight with attendant increased mortality and decreased egg production. In addition, as pointed out by Quisenberry (1958) - "with the increased cost of pullet chicks and low prices for market hens, more attention is being given to pullet rearing systems." In the restrictive feeding program, all chicks are fed a full energy starter ration for the first 7 to 9 weeks and the pullets are then separated randomly into groups. They are housed in cages, pens, or put out on range, depending on the procedure of the investigating group and climatic conditions. The control pullets are fed a high-energy growing ration (900 to 1,000 Calories/pound) ad libitum. In one of the two principal methods of restrictive feeding, other groups are fed the same ration but are limited so that they receive only 50 to 75 percent of the amount consumed by the control group. In the second method of restriction, still other groups of pullets received rations high in fiber and low in energy (500 to 675 Calories/pound) ad libitum. Pullets on the high-fiber diet consume much more feed by weight but are reduced in their energy intake by the bulk of the diet. At the end of 20 to 26 weeks, the groups of pullets are housed in laying cages or pens and fed full-energy layer rations.

Bruins (1958), working with both Leghorns and broiler-breeder type birds housed in cages, reported that restricting the energy intake up to 20 or 21 weeks by both methods of restrictive feeding caused slight delays in the beginning of egg production (3 to 6 days) but resulted in longer productive lifespan and greater egg production. Thomas and Albritton (1959) restricted the intake of high-energy rations of Single Comb White Leghorn pullets on range to 50 or 75 percent of the level consumed by a control group. Like Bruins, they also reported a larger net income over feed costs on the restricted feeding program.

J. H. Quisenberry (1958), using hybrid light-breed egg-production strains, investigated both the high-fiber and mechanical methods of restricting feed for pullets on range. He found that severely restricted groups showed delayed sexual maturity of 6 to 31 days, thus agreeing with the two investigations discussed previously. However, he found no correlation between diet and egg production, egg size, or layer mortality. The feeding of a basal diet (993 Calories/pound and 17.9 percent of protein) plus 5 percent of added fat at 70-percent level did not delay sexual maturity and combined very good egg production with high feed efficiency. He concluded that "if further research demonstrates that caloric restriction is beneficial, economy may well dictate that it will be carried

out through the mechanical restriction of high caloric diets."

Restriction of the diet of laying hens seems more applicable to the heavy broiler-breeder types. Hill (1958) pointed out that the light high-production-layer types of breeds such as Leghorns have demonstrated their ability to use high-energy rations supplemented with fat and consume only that amount of energy necessary to maintain a highly efficient rate of egg production. Recent findings indicate that the heavy-breed type of layer is unable to control the rate of feed consumption satisfactorily when fed a ration high in energy. Singsen et al. (1958) restricted the energy of White Rock layers both by feeding low-energy feeds ad libitum and by restricting high-energy rations to 70 to 80 percent of that consumed by the controls. The controls full fed on high-energy diet laid well but grew fat and had a higher mortality rate. The hens on either type of restricted diet kept their weight normal, and had a high production rate and a lower rate of mortality. Those hens fed a high-energy feed on a restricted basis produced eggs at the lowest cost and did not waste feed. It is apparent, therefore, that the feeding of high-energy rations to either immature replacement pullets or laying hens on a controlled basis offers considerable promise for the competitive use of fat at present prices.

Egg quality, fertility, and hatchability are important factors as well as egg production. Carver et al. (1955) reported that the inclusion of 3 percent of tallow in the diet of laying hens did not adversely affect the flavor of either fresh or stored eggs. Orr et al. (1958) found that the addition of 2-1/2 or 5 percent of animal fat to a basal diet had no effect on the quality of fresh eggs.

Mottling of egg yolk in storage and abnormal color are important factors in egg quality. According to Miller et al. (1957) the addition of 5 or 10 percent of choice white grease to the diet did not increase mottling of yolks during storage for 5 days at room temperature. Sherwood (1959), in a review on egg quality, reports that 2 percent of an unsaturated fish oil causes very pale egg yolks. This is attributed to oxidation of carotenoids in the presence of the readily oxidizable unsaturated fats. Vegetable oils also contain unsaturated fats but are supplied with natural antioxidants. Free gossypol present in crude cottonseed oil and cottonseed meal containing residual oil causes pink egg whites and salmon colored yolks, particularly in stored eggs. This phenomenon has been investigated by Heywang et al. (1954, 1955) and Evans et al. (1957, 1958). The latter (1958) reported that this effect was not caused by other vegetable oils such as sesame, safflower, tung, peanut, rice bran, linseed, soybean, and corn oils. According to Sherwood (1958) these discolorations observed on feeding cottonseed oil containing gossypol are due to the weakening of the vitelline membrane surrounding the yolk. Masson et al. (1957) report that kapok seed oil and sterculia foetida oil will also cause pink whites. The causative factor in sterculia foetida oil is sterculic acid.

Hatchability of eggs appears to be affected by the inclusion of certain oils in diets. Ringrose et al. (1941) found hatchability decreased from a high of 80 percent to less than 30 percent when 3.6 percent of crude cottonseed oil was included in the diet. Hydraulic-pressed cottonseed oil and winterized cottonseed oil when fed at the 5-percent level depressed hatchability drastically according to Naber and Morgan (1957). They found that the extra-embryonic circulatory system was disrupted at 4th day of incubation, while at the 18th day there were hemorrhages in the embryo and the extra-embryonic blood vessels. Refined cottonseed oil did not depress hatchability, but heating and aerating this oil for 300 hours at 95° C. did depress hatchability. Their conclusion that the causative factor is the same in both cases does not conform to available information regarding oils heated in the presence of air (Kaunitz et al. 1957). Fortunately, the effect of crude cottonseed oil on hatchability is not common to all fats. The addition of 4 and 8 percent of stabilized lard or of 6.6 percent of stabilized yellow grease to rations of laying hen did not influence fertility or hatchability, according to Lillie et al. (1957) and Hochreich et al. (1958).

Miscellaneous physiological effects have resulted from the unwise use of certain types of fat in otherwise properly formulated rations. For example, byproducts of certain types of industrial fat processing, as well as a few naturally occurring fats, may produce undesirable physiological effects in chickens and other animals. The outbreak late in 1957 of chicken edema disease, popularly known as "water belly", caused the death of several million chicks and resulted from the use in chick feeds of

low-grade byproducts derived from fatty acid processing. This particular processing operation not only caused extensive degradation of some fat components but, in the process of removing much of the fatty acids, acted to concentrate the degradation products and also the unsaponifiable matter in which the causative factor was found. Schmittle et al. (1958) described the symptoms and summarized much of the background information on this disease. Edwards (1958) reported that the fatty byproduct in the ration of laying hens stopped egg production after 55 days, decreased hatchability of fertile eggs, and resulted in an abnormal number of yolks remaining in the body cavity.

The toxic effects of this industrial fatty acid byproduct appears to be highly specific for chicks. For example, turkey poults and ducks do not suffer the same adverse effects as chicks (Potter et al., 1959). Friedman et al. (1959) showed that the unsaponifiable fraction from this byproduct produced edema in chicks but not in young rats, although some depression in growth was noted in the latter. These workers also examined the unsaponifiable material extracted from the carcasses of chicks that had been fed this toxic byproduct and found 25 percent more unsaponifiable material per unit weight of chicken than in the control chicks. This material, when fed to other chicks, produced the edema disease, an indication that the toxic material had been deposited in the flesh. This finding raises grave questions concerning human consumption of the flesh of animals fed such severely degraded fats.

A fatty acid fraction from this industrial byproduct, which did not form an adduct with urea, was also toxic. When fed to rats in the amounts of 0.4 ml. per day for 2 days, it caused death by the forth day. Two doses of 0.2 ml. caused a marked weight loss from which recovery began on about the fourth day. Chicks reacted similarly but seemed to be more resistant to the lethal effect of direct feeding. Friedman et al. also noted that those physiological effects were similar to those obtained by feeding a comparable fraction derived from extensively heated cottonseed oil and to those observed by Crampton et al. (1951) with heated linseed oil. Waste material such as "skims" and residues from drying oil and varnish-making plants would be expected to contain similar toxic materials. Kaunitz et al. (1957) made comparable observations on the toxicity of heat-oxidized cottonseed oil and lard. Their reports suggest that fatty residues from deep-fat frying may also be questionable, and that any material from industrial fat processing, or any new unusual natural oil, should be thoroughly tested and its value established for all types of animals before it is supplied for feeds for these animals.

Turkeys

Investigations on the value of high-energy diets containing added fats for turkeys have lagged considerably behind comparable studies for chickens, although research on the C/P ratio and requirements of turkeys for proteins, amino acids, vitamins, and minerals is moderately well advanced. It seems reasonable to expect, however, that many of the findings in studies with chickens would apply in a general way to turkeys.

Poults:--All investigators have reported gains in feed efficiency when the energy of poult rations has been increased by adding fat but have obtained conflicting results as to the value of added fat for improving the rate of growth. This anomaly appears in part to be due to a difference in response of various strains of turkeys. For example, Sunde (1954) found that 2.5 percent of soybean oil, stabilized white grease, or prime tallow in rations in which the protein level was maintained constant, improved the growth response of Broad-Breasted Bronze poults during the first 6 weeks. The use of 5 percent of these three fats did not further improve growth. Only tallow improved the growth of Nebraskan poults (a smaller strain). In all cases, however, each fat improved feed efficiency in proportion to the amount used. Similarly, Biely and March (1954) reported that the addition of stabilized tallow to rations at various protein levels increased the growth of both male and female Broad-Breasted Bronze poults in the first 10 weeks, whereas only the female poults of Beltsville Small White grew faster when tallow was added. A protein level of 28 percent was optimum for best growth and feed efficiency.

The results of Patterson et al. (1955), Lockhart and Thayer (1955), and Day and Hill (1957) indicated that a relatively high protein level (about 28 to 30 percent) and a narrow C/P ratio range (25:1 to 30:1) are quite critical for the first 6 to 8 weeks. Atkinson et al. (1957) obtained optimum growth with Broad-Breasted Bronze poults on feeding starter rations containing 28 percent of protein, 840 Calories/pound

(C/P 30:1) and 4.5 percent of either methyl esters derived from cottonseed oil or stabilized animal fat. However, rations containing 15 percent of either fatty material were used efficiently.

The full potential of added fat in starter rations is not realized without an adequate supply of protein properly balanced with respect to amino acids. This fact is well illustrated by the investigations of Waibel (1956), in which he found that the addition of 10 percent of tallow to a diet containing 28 percent of protein (C/P 33:1) resulted in no improvement in growth in Broad-Breasted Bronze and Broad-Breasted White poults, whereas the addition of 10 percent of tallow to a ration containing 32 percent of protein resulted in a marked increase in growth. Further improvement in growth was obtained when the same level of protein supplemented with methionine was used with 15 percent of tallow. Later, Waibel (1958) obtained maximum growth (1,574 grams) for Broad-Breasted Bronze poults at 6 weeks by using supplements of methionine, lysine, and chlorotetracycline in a ration containing 10 percent of tallow and 33 percent of protein (C/P 25.6:1) during the first 3 weeks and decreasing the protein level to 26.1 percent (C/P 36.4:1) in the second 3 weeks.

Thayer and Dunkelgood (1957) investigated the feeding of very high-energy starter rations containing over 35 percent of added fat to 3,000 Broad-Breasted White poults. These rations were fully supplemented and contained, in addition to practical-type ingredients, such materials as dried egg solids, casein, starch, and biotin, which are at present too costly for general use. Maximum growth was obtained at a protein level of 33 percent and maximum efficiency with slightly lower growth at the 36-percent protein level. In both cases the C/P ratio was 55:1, on the basis of metabolizable energy of the diet. Assuming metabolizable energy to be approximately 1.5 times the productive energy, this was a C/P ratio of 36.6:1 on a productive-energy basis. At 8 weeks feed efficiencies of 1.25 to 1.4 were obtained on the high-fat experimental diets compared with 1.8 on a practical control diet.

After 8 weeks, the poults' requirement for protein decreases. The work of Day and Hill (1957) and Carter et al. (1957) indicated that during the 8- to 16-week growing period, good efficiency and satisfactory growth should be obtained on rations containing 800 to 950 Calories and C/P ratios in the range of 45:1 to 55:1.

Finish is an important factor in carcass quality in preparing a turkey for market. In recent years, it has been economically advantageous to market turkeys at about 16 weeks of age as fryer-roasters. The problem of finish, as well as dryness and variability in tenderness, is even more critical at this age than in more mature turkeys at 20 to 26 weeks. Marsden et al. (1952) recommended high fat levels in rations of birds to be marketed at 16 weeks, on the basis of data indicating increased tenderness and juiciness.

Combs, Helbacka, and Romoser (1958) carried out a carefully planned investigation of the effect of implanted 15 milligram pellets of diethylstilbestrol, stabilized fat (hydrolyzed animal and vegetable fat), and C/P ratio on growth, feed conversion, and a number of factors affecting carcass quality. Twelve groups, each consisting of 26 to 30 11-week-old Broad-Breasted Bronze turkeys (both sexes), were used in a 3-week experiment. The initial 11-week weight averaged 3.7 kilograms for the males and 2.9 kilograms for the females. The effect on growth and feed conversion are shown in table 9. A C/P ratio of 44:1 resulted in greater gains in weight with either 2 or 10 percent of added fat and 10 percent added fat also produced greater

TABLE 9.--*Effect of fat level, C/P ratio, and diethylstilbestrol pellets on growth and feed conversion of turkey fryers*[1]

Fat added, percent	Calorie-protein ratio	Energy (productive)	Protein	Diethyl-stilbes-terol[2]	Average gain (11-14 weeks)			Feed efficiency
					Males	Females	Both sexes	
	C/P	*Cal./lb.*	*Percent*		*Grams*	*Grams*	*Grams*	*Feed/gain*
2.............	44:1	968	22.0	-	1,806	1,175	1,491	3.46
	44:1	968	22.0	+	1,955	1,465	1,710	3.55
	60:1	1,032	17.3	-	1,710	1,130	1,420	3.75
10............	44:1	1,070	24.3	-	1,828	1,248	1,538	3.23
	44:1	1,070	24.3	+	2,096	1,506	1,801	3.29
	60:1	1,149	19.0	-	1,792	1,216	1,504	3.21

[1] Adapted from Combs, Helbacka, and Romoser (1958).
[2] Diethylstilbesterol pellets (implanted); contained 15 mg. of active material.

gains in weight and better feed conversion than 2 percent of added fat. The groups receiving the diethylstilbestrol implants gained the most weight, the rate of feed conversion being about the same as comparable nonimplanted groups.

In regard to carcass quality, there were no differences in dressed pin feather score with any group. Diethylstilbestrol resulted in increased carcass fat content which was reflected in higher abdominal fat, liver weight, and dressed finish score, increased dripping losses during cooking, and lower volatile cooking loss. Diethylstilbestrol was more effective with females and with birds receiving rations with 10 percent of added fat as measured by better finish. There was little difference in carcass quality between comparable groups receiving 10 percent or 2 percent of added fat, except that turkeys on 10 percent of added fat and a 60:1 C/P ratio had the highest dressed finish score. In the absence of diethylstilbestrol, turkeys on a 60:1 C/P ratio had a higher dressed finish score, abdominal fat deposition, and a higher percentage of drippings during cooking than did those on a 44:1 C/P ratio. Females were more affected than males, having higher abdominal fat and larger livers. A taste panel of 20 persons did not find any differences in acceptability in the turkey meat resulting from various treatments. Thus the effects of diethylstilbestrol implants on young turkeys is primarily on the finish of the carcass. Chicken broilers normally have satisfactory finish, so such implants, or hormone supplementation, are not commonly used in broiler production.

It is common practice to market turkey hens at 20 to 22 weeks of age and toms at 24 to 26 weeks. Couch (1959) recommends that turkeys from the end of the 16th week until sent to market receive rations as high in energy as it is economical to provide. At prices then prevailing no more than $2\frac{1}{2}$ percent of fat can be used, although in the final 2 to 4 weeks 10 percent of fat may be advantageous for speeding up the finishing. Toms require 18 percent of protein in their rations up to 20 weeks, while hens need only 15 to 16 percent. Carlson (1957) also reported that increased energy in the ration improved finish and fleshing.

Klose et al. (1951, 1953) reported that the addition of 2 or 5 percent of linseed oil to the rations of Broad-Breasted Turkey Toms during the 20- to 28-week-finishing period produced fishy off-flavors in the roasted carcasses of freshly slaughtered birds. This same off-flavor was produced also by 2 percent of sardine oil but not by 5 percent of coconut oil or 2 percent of either corn oil, soybean oil, or beef fat. There was no appreciable increase in off-flavor after freezing and storing for several months.

Laying turkey hens:--The relatively few investigations on diets of laying turkey hens have shown that their energy requirements are moderately low. Dymsza et al. (1954) during the latter part of the breeding season fed white Holland turkey hens rations varying in productive energy from 249 to 882 Calories/pound. They noted no difference in body weight, rate of egg production, or fertility. However, the hatchability of fertile eggs increased with increasing energy in diet. Robblee and Clandinin (1959) reported that Broad-Breasted Bronze hens showed no difference in body weight and egg production or in fertility and hatchability of eggs on rations containing either 15 or 17 percent of protein and having a C/P ratio ranging from 41:1 to 59:1. That these investigators noted no effect of energy level on hatchability of fertile eggs may be explained by the fact that their experimental rations were generally higher in energy than those of Dymsza. On the other hand, Creger et al. (1958) reported on a study in which a complete basal diet was supplemented with as much as 12.5 percent of fat. Their results indicate a slight increase in egg production, a definite improvement in feed efficiency, and a prevention of body weight loss during the period of egg production with the addition of fat to the diet.

Geese

Geese are the fastest growing of all poultry and the most efficient in feed conversion, particularly during the first 8 to 10 weeks. They are also practically free of disease and excellent foragers on range. Nevertheless, they are among the least important of domestic meat-producing birds. This low standing in the economy is reflected in the deficiency of research data on their feed requirements (Waibel, 1958).

A full-grown goose is extremely fat and, although attractive to a few, is generally unpopular with the modern housewife. On the other hand, a "goose broiler" does not suffer from over-fatness and can be marketed at the end of a period of high efficiency in feed conversion.

Waibel (1958a) reported on the performance of Emden-Toulouse hybrid goslings fed starter rations of varying protein and energy content carefully formulated from

practical ingredients and supplemented with a mineral and vitamin mix. Data from these investigations are shown in table 10.

TABLE 10.--*Performance of goslings fed rations of varying protein and energy content* [1]

Ration	Tallow[2]	Methionine	Protein	Energy (productive)	Calorie-protein ratio	Weight at 4 weeks	Feed efficiency
	Percent	*Percent*	*Percent*	*Cal./lb.*	*C/P*	*Pounds*	*Feed/gain*
I (bulky)......	--	--	20.2	755	37.3	4.38	2.08
II............	--	--	21.2	912	43.0	5.10	1.91
III...........	5	0.5	24.1	997	41.5	5.12	1.73
IV............	15	.1	28.1	1,108	39.5	5.41	1.44
V.............	2.5	.1	28.0	945	33.7	5.10	1.73

[1] Adapted from Waibel (1958).
[2] Stabilized, bleached fancy tallow.

At the end of 4 weeks, the goslings receiving the bulky low-energy ration had not grown so fast as those receiving the higher energy rations. Those receiving the high-fat, high-protein ration grew the fastest and showed excellent feed efficiency (feed/gain - 1.44) for a 5.4 pound bird.

Waibel (1958a) also reported on some experiments with Emden goslings fed on Rations II and V (table 10). At the end of 3 weeks, the goslings receiving the high-protein ration (V) containing 2.5 percent of tallow were heavier and showed better feed utilization. Each of the two groups were then divided and part of the goslings were put on pasture and the rest were reared in confinement. At the end of 6 and 9 weeks the goslings that had received the low-protein ration (II) supplemented after the third week with whole corn, fed free choice, were more efficient in feed conversion than those that had been continued on an all-mash program with the high-protein ration (V). This was true either on pasture or in confinement. At 9 weeks, all groups averaged about the same weight (9.8 to 10.0 pounds).

Goose broilers are easily brought to a desirable finish and good fleshing in contrast to the difficulties experienced with chicken and turkey broilers. Snyder and Orr (1953) reported that goose broilers were well accepted in the consumer market at 8 to 14 weeks of age and were superior to geese 19 to 21 weeks of age in percentage of edible meat. Swanson and Canfield (1955) studied the dressing losses, cooking losses, and yield of edible meat of geese 8 to $16\frac{1}{2}$ weeks of age. The percentage yields of edible meat after roasting were not greatly different for various ages. The younger geese had a slightly higher proportion of bone, while the older geese yielded a higher proportion of pan drippings.

Ducks

Little information is available on the energy and protein requirements of ducks. Rice et al. (1954) reported the results of feeding 4 lots of 20 growing ducks each. Two pens were fed animal fat (tallow and grease), one pen was fed acidulated soy foots, and another pen, acidulated cottonseed oil foots. All fats were added to the basic ration at the 5-percent level. Reduced feed requirements per pound of gain were noted in each case, the magnitude of the reduction being comparable with that observed in feeding chicken broilers. Taste panels did not detect any difference in flavor between experimental and control animals.

Scott et al. (1957) studied the effect on carcass fat in ducklings of reducing the energy content of the diet from 970 to 850 Calories per pound and gradually increasing the protein content from 16 to 28 percent. The carcass fat content was reduced from 32.7 to 24.2 percent, but the weight of the ducklings and feed efficiency were also reduced, thus increasing the cost of raising the ducks.

SWINE

The classical work of Ellis et al. (1926, 1931) on the feeding of various fats at different levels to swine has contributed substantially to our knowledge of the effects of fat in the diet. He showed that when fats were included in the diet above levels of a few percent, the depot fat tended to assume the composition and the physical characteristics of the ingested fat. In this way, he demonstrated that "soft pork" resulted from the inclusion of too much oil-containing material, peanuts for example, in the swine rations. Although his studies successfully demonstrated that relatively large proportions of fat in the diet could be tolerated and assimilated by swine, it remained for later workers to study the efficiency and economic aspects of inclusion of fat in swine rations.

Perry et al. (1953) reported that feeding 1 to 10 percent of lard in place of corn in the growing and fattening ration was without

effect on the growth rate of swine. However, average daily feed consumption was lower with those lots containing higher levels of lard and less feed was required per 100 pound gain. Kropf et al. (1954) fed mixed rations containing 10 and 15 percent of raw ground beef fat successfully to hogs. There were no consistent increases in weight gain, but added fat increased feed efficiency. Anderson et al. (1957) reported on the feeding of mixed rations containing approximately 14 percent of digestible protein and either 10 percent of "prime burning lard" or 10 percent of tallow to Duroc and Berkshire pigs. Both growth rate and feed efficiency were improved.

Barrick, Blumer, and Brown (1954) conducted two feeding experiments with pigs from weaning to market weight. In the first experiment (in winter), pigs fed diets containing 10 percent of beef fat gained 2.37 pounds per day with a feed requirement of only 288 pounds per hundred pounds gain. This was in contrast to a daily gain of 2.02 pounds and a feed requirement of 347 pounds per 100-pounds gain for the pigs receiving the diet without added fat. In the second trial (in summer), the difference in the rate of gain was less marked, but the advantage of the diets with added fat in promoting feed efficiency was just as great. Diets containing 10 percent of brown grease or 10 percent of beef fat were compared with one without added fat. The animals receiving the diets with added fat consumed slightly less weight of feed daily but used this feed very efficiently.

Although a pound of fat contains approximately as much energy as 2.5 pounds of corn, it does not contain any protein. For this reason when fat replaces corn in a mixed ration, additional protein must be added. In these experiments, 12.4 pounds of the corn in 100 pounds of the control diet were replaced by 10 pounds of fat and 2.4 pounds of soybean meal. The control diet contained 69.3 percent of corn, 22 percent of soybean meal, 5 percent of alfalfa meal, 2 percent of bone meal, 0.7 percent of limestone, as percent of salt, 0.5 percent of trace mineral, vitamin and antibiotic mix. With corn priced at 3 cents per pound and soybean meal at 4.5 cents per pound, the animal fats used in these experiments were estimated to be worth 10 cents per pound. The authors recommended that the fat content of purchased swine feeds be considered since, other ingredients being equal, the feed with the highest fat content would have the most value.

Sewell et al. (1957) studied the relationship of protein requirements to energy levels in feed for growing swine. In their experiments, 60 weanling pigs averaging approximately 32 pounds live-weight were allotted at random into 12 groups. These groups in turn were assigned at random to a 3 x 4 factorial experiment in which the main treatment effects were three energy levels and four protein levels. The energy density of the rations was varied by the addition of different quantities of stabilized prime tallow. Levels of 0, 5, and 10 percent of added tallow were used. The four protein levels studied were 11, 14, 17, and 20 percent, as calculated from crude protein analysis (N x 6.25) of the feed ingredients used. At the termination of the first 45 days of the experiment, protein levels were reduced to 8.7, 11, 14 and 17 percent, respectively, for an additional 39 days. The basal ration was composed of ground yellow corn, soybean meal, and alfalfa meal, and was adequately fortified with vitamins and minerals. All pigs were confined to concrete drylot with feed and water provided ad libitum. Liveweight gains were obtained individually on the pigs at 2-week intervals and group-feed-consumption records were maintained. At all protein levels, feed efficiency increased with increasing levels of fat. Data based on averages for each group of pigs are shown in table 11.

Baird[2] has also studied the relationship of levels of fats and protein to performance and carcass quality of growing-fattening hogs. He used a prime grade of tallow and choice white grease. All fats were stabilized. As shown in table 12 the ration containing 8 percent of tallow and 15 percent of protein with a C/P ratio of 61.9:1 was the most efficient. Rations containing only 11 percent of protein resulted in decreased growth rates. There were no marked differences in carcass grades.

Noland and Scott (1959) found that the addition of 10 percent of stabilized animal fat to swine rations containing 16 percent of protein increased the average daily gain from 1.65 pounds to 1.81 pounds. In feeding this amount of fat to pigs weighing from 20 to 200 pounds, the length of their feeding period was reduced by 10 days and 80 pounds of feed was saved per pig. In

[2] Baird, D.M. Private communication, University of Georgia Experiment Station, 1957.

TABLE 11.--*Effect of different protein and fat levels on performance of weanling pigs*[1]

(Combined feeding period of 84 days. Data expressed as averages per animal.)

Items	Tallow added 0	Tallow added 5 percent	Tallow added 10 percent	Average
Protein, 11 percent:				
Pigs....................number....	5	5	5	
Initial weight.........pounds....	33.10	30.50	32.40	32.00
Final weight.............do......	162.60	145.20	145.80	151.20
Daily gain...............do......	1.56	1.38	1.37	1.44
Feed per pound gain......do......	3.51	3.45	3.11	3.36
Daily feed intake........do......	5.48	4.76	4.26	4.83
Protein, 14 percent:				
Pigs....................number....	5	5	5	
Initial weight.........pounds....	31.50	32.50	32.20	32.10
Final weight.............do......	168.80	187.80	186.20	180.90
Daily gain...............do......	1.65	1.87	1.86	1.79
Feed per pound gain......do......	3.20	2.84	2.66	2.90
Daily feed intake........do......	5.28	5.31	4.95	5.18
Protein, 17 percent:				
Pigs....................number....	5	5	5	
Initial weight.........pounds....	31.70	34.90	30.80	32.50
Final weight.............do......	184.10	184.00	185.40	184.50
Daily gain...............do......	1.84	1.80	1.86	1.83
Feed per pound gain......do......	3.30	3.04	2.62	2.99
Daily feed intake........do......	6.07	5.47	4.87	5.47
Protein, 20 percent:				
Pigs....................number....	5	5	5	
Initial weight.........pounds....	32.00	31.30	31.00	31.40
Final weight.............do......	163.00	176.60	189.00	176.20
Daily gain...............do......	1.58	1.75	1.90	1.74
Feed per pound gain......do......	3.04	2.89	2.75	2.89
Daily feed intake........do......	4.80	5.06	5.23	5.03
Averages:				
Pigs.............total number....	20	20	20	
Initial weight.........pounds....	32.10	32.30	31.60	
Final weight.............do......	169.60	173.40	176.60	
Daily gain...............do......	1.66	1.70	1.75	
Feed per pound gain......do......	3.26	3.06	2.79	
Daily feed intake........do......	5.41	5.15	4.83	

[1] Sewell et al. (1957)--private communication.

rations containing only 12 percent of protein, 8 percent of added fat actually depressed growth in the 40- to 75-pound weight range. Pigs weighing more than 125 pounds gained rapidly and efficiently on feeds containing 12 percent of protein and 8 percent of added fat.

Perry et al. (1959) reported the results of their studies regarding the effects of adding lard up to 20 percent to practical-type swine rations containing from 14 to 20 percent of protein. As the fat content of the ration was increased, feed consumption decreased. Pigs on rations containing 20 percent of lard consumed 3.9 pounds of feed per day compared with 5.3 pounds on rations containing no added fat. Within the limited range of protein levels studied, 14 to 20 percent, the level of protein had no significant effect on growth rate or feed efficiency when different amounts of fats were included in the diet. The C/P ratio apparently was not as critical for swine as for poultry. The authors also noted that fat added to the diet increased the thickness of the back fat layer; for 125-pound pigs fed a 5-percent level of fat, the thickness of back fat increased about 15 percent, whereas at the 20-percent level it increased 30 percent. They concluded that 10 percent of added lard was about the best level; it produced a 20-percent increase in the rate of gain.

TABLE 12.--*Relationship of levels of inedible fats and protein to performance and carcass quality of growing-fattening hogs*[1]

(Data expressed as averages per animal.)

Items	Lot 1, low fat,[2] low protein	Lot 2, low fat,[2] medium protein	Lot 3, low fat,[2] high protein	Lot 4, high fat,[2] low protein	Lot 5, high fat,[2] medium protein	Lot 6, high fat,[2] high protein
Pigs................number....	7	7	7	7	7	7
Initial weight......pounds....	45.1	47.4	46.3	46.6	47.6	48.9
Final weight..........do......	199.3	205.6	199.0	196.4	203.3	199.3
Daily gain............do......	1.52	1.63	1.63	1.57	1.64	1.61
Feed per cwt. gain...do......	322.3	306.0	323.7	285.3	251.9	283.4
Daily feed............do......	4.89	5.12	5.48	4.73	4.36	4.75
Fat back............inches....	1.67	1.70	1.52	1.75	1.65	1.55
Carcass grade, manual[3]........	1.3	1.0	1.6	1.0	1.2	1.5
Refractive index:						
Back.........................	1.4597	1.4591	1.4590	1.4592	1.4592	1.4593
Leaf.........................	1.4583	1.4583	1.4584	1.4586	1.4584	1.4581
Crude Protein......percent....	11.0	15.2	19.3	11.1	15.0	19.2
Therms per cwt................	85.4	84.8	84.0	93.8	93.2	92.5
C/P ratio[4]....................	78.0	55.7	43.4	84.6	61.9	48.2

[1] Baird (1957)--private communication.
[2] Tallow added at 4 and 8 percent for the low- and high-fat groups, respectively.
[3] Manual grade: 1 Hard; 2 Medium Hard; 3 Medium Soft; 4 Soft.
[4] Calories of productive energy per pound for each percentage of crude protein in ration.

Carcass quality of swine is definitely affected by the proportion and type of fat used in the diet. The previously mentioned work of Ellis and coworkers showed that "soft fats" resulted from the inclusion of more than a low percentage of oils in the diet of swine. Other problems can also arise, such as those related to color, flavor, and odor. A number of investigators have studied various aspects of the inclusion of fish oils of several types of swine feed. Brown (1931) found that feeding a ration containing 14 percent of menhaden oil to swine for 5 weeks before slaughter resulted in a marked yellow color in the carcasses. Moreover, fatty acids characteristic of the menhaden oil were present in the lard of the animals. Further, Vestal et al. (1945) found that 0.5 percent of menhaden oil added to swine rations containing 10 percent of fish meal resulted in a fishy flavor in cooked pork from all animals fed. In the feeding of oil of pilchard (California sardine), Anglemier and Oldfield (1957) obtained similar results.

Fish oils have been modified by heat polymerization in attempts to overcome these undesirable effects. However, reduced growth rates and other undesirable phenomena have resulted. If problems of carcass quality are to be avoided, it is essential that at even moderately high levels of feeding, the fat should be somewhat similar to pork fat in composition. Grease and tallow would seem to meet this requirement most closely.

The use of starter feeds for baby pigs has stimulated several studies on the application of fats for the purpose. The relation between digestibility and certain characteristics of fats and oils has been studied by Lloyd et al. (1958, 1958a). A highly significant inverse relation was found between apparent digestibility by early weaned pigs and the molecular weight of the fatty acids of various fats. This effect was accentuated in the youngest of the pigs and became less marked as the pigs approached 8 weeks in age. They found little relation between saturation of the fats and apparent digestibility.

Peo et al. (1957) studied the protein and fat requirements of baby pigs. At 4 weeks gains in growth, averaged across fat levels of 0, 2.5, 5, and 10 percent, reached a maximum at 20 percent protein. The added fat improved appearance of the pigs and physical characteristics of the ration, and had no significant effect on the rate of growth.

In conclusion, feeding experiments on growing and fattening swine point to considerable possible advantage resulting from the addition of fat to their rations. When proper adjustments of protein levels in the feed are made and if requirements of other growth essentials are met, certainly additions of fat (up to 10 percent) in the ration have given good results.

CATTLE

Beef Cattle

A trend toward a lower fat content of feed for cattle and other stock resulted from the increasing use of solvent extraction for removing oil from seed meals. The oil content of the extracted meal usually is about 1 percent compared with 5 to 6 percent of oil in meals obtained by previous hot-pressing methods. This trend toward a lower fat content was noted by Willey et al. (1952), who investigated the effect of this change on the feeding of Hereford steer calves. Groups of four calves were fed high- and low-energy-level diets containing solvent-extracted cottonseed meal for comparison with hydraulic-pressed cottonseed meal and added cottonseed oil. The fat (oil) contents of the feeds were 2.9 and 7.5 percent. Their feeding results show that the rations with the higher fat content gave markedly increased feed efficiency and growth at least comparable to that of rations with low-fat content.

Matsushima and Dowe (1954) investigated the use of edible grade tallow and corn oil in feeds for yearling Hereford steers. The tallow and corn oil were added to the ration in the form of pellets containing about $5\frac{1}{2}$ percent of fat. The level of fat in the ration was about 2.5 percent. The fats were not stabilized and rancidity developed in the corn-oil pellets, probably causing destruction of vitamin A since deficiency symptoms were noted. The deficiency was corrected by doubling the supplement of this vitamin. A summary of their results on the feeding experiment is shown in table 13. Compared with steers fed standard ration, those receiving tallow and corn oil pellets did not show as good growth gains. However, the economy of gain was in favor

TABLE 13.--*Performance of steers on rations containing tallow and corn oil*[1]

(Data expressed as averages per animal.)

Items	Ration 1	Ration 2	Ration 3
	Soybean meal	Beef tallow (pellets)	Corn oil (pellets)
Initial weight.............pounds....	855	859	852
Final weight.................do......	1,172	1,159	1,113
Total gain...................do......	317	300	261
Average daily gain...........do......	2.11	2.00	1.74
Daily feed consumption:			
Ground shelled corn.........do......	17.1	--	--
Ground ear corn.............do......	--	9.4	9.2
Beef tallow pellets.........do......	--	12.2	--
Corn oil pellets............do......	--	--	11.9
Vitamin A supplement......grams.....	2.97	4.03	3.78
Brome hay.................pounds....	2.8	2.0	1.8
Soybean meal................do......	0.9	--	--
Feed consumed per cwt. gain:			
Ground shelled corn.........do......	807.9	--	--
Ground ear corn.............do......	--	469.3	528.4
Beef tallow pellets.........do......	--	608.3	--
Corn oil pellets............do......	--	--	683.1
Vitamin A supplement......grams.....	140	202	217
Brome hay.................pounds....	134.7	101.7	103.8
Soybean meal................do......	43.2	--	--
Feed cost per cwt. gain[2]...dollars....	27.67	26.49	31.96
Market weight..............pounds....	1,113	1,098	1,058
Selling price per cwt......dollars....	20.25	20.25	20.25
Dressing percent (warm weight)..do....	62.96	60.24	60.44
Carcass grade.........................	Choice	Choice	Choice

[1] Adapted from Matsushima and Dowe (1954).
[2] Feed prices per pound: Corn at 3¢; ear corn at 2.4¢; beef tallow pellets at 2.28¢; corn oil pellets at 2.61¢; vitamin A supplement at $1.30; and brome hay at 0.75¢.

of the group of steers fed the beef-tallow pellets, even on the basis of 9 cents per pound for the edible tallow.

Schweigert and Wilder (1954) conducted feeding studies with 24 good-quality Hereford steers. One group of 12 steers received a practical basal ration, while a second group received the same ration except that 1 pound of stabilized fancy tallow was substituted in the ration for $2\frac{1}{2}$ pounds of corn. At the end of the feeding period, the animals were slaughtered and the carcasses inspected and graded through the cooperation of a local meat-packing company. The results on the rates of gain and carcass yield (table 14) show that at least low levels of tallow can be efficiently utilized by steers.

TABLE 14.--*Gain and carcass yield of steers on ration containing fat*[1]

Ration	Weight				Carcass Yield
	Initial	Final	Daily gain	Carcass	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
Basal...............	748	959	1.94	548	57.1
Basal + Fat[2].........	758	975	1.99	555	56.9

[1] Adapted from Schweigert and Wilder (1954).
[2] One pound fat substituted for 2 1/2 pounds of corn per day.

Barrick, et al. (1954a) also showed that animal fats can be substituted effectively for a part of the grain in rations for fattening steers. In their test, the animals were on full feed for 141 days. The group receiving 5 percent of added animal fat made faster gains on less feed than the group receiving the control diet. The carcasses from the group fed added fat also graded slightly higher than those from the group fed the control ration.

Newell (1955) reported the influence of tallow and yellow grease on the commercial feed lot performance of 196 fattening steers. His results tended to confirm earlier experimental studies--cattle fed 2.25 percent of tallow and 4.5 percent of yellow grease showed improved feed efficiencies over the control group. A group fed 4.5 percent of tallow, however, did not do so well as the controls. This fact is attributed to a possible disturbance of the rumen microflora during the early weeks of the feeding period.

Bohman (1957) observed that the inclusion of animal fats in the diet of wintering animals was not advantageous on the basis of cost, even though it subsequently led to increased summer gains. In separate studies, however, Bohman et al. (1957) found that animal fats could be used economically and advantageously in the feed lot for fattening cattle, thus confirming previous observations in this regard.

Carcass quality has been little affected by the inclusion of fats in the rations of beef cattle in the proportions investigated. Such slight effects as have been reported have generally been favorable, indicative of a slightly higher grade.

Cattle appear to be more sensitive to palatability changes associated with adding fats to feeds according to Schweigert (1959).[3] He noted that the influence of palatability is difficult to measure and suggested an upper limit of about 1 pound of added fat per day. Several investigators have noted that when fats are added to their rations the cattle are slow to get "on feed." On the other hand, some operators have used fats rather extensively when economic conditions were favorable.

Dairy Cattle

From studies carried out two-thirds of a century ago, Wood (1894) concluded that although certain fat additions to cows' rations caused a temporary increase in butterfat percentage, there was a return to normal with continued feeding. He tried

[3] Schweigert, B.S. Private communication, 1959.

palm oil, corn oil, cottonseed oil, stearine, and coconut oil. Lindsey (1908) obtained similar results with linseed and soy oils. Wing (1895) fed tallow in varying amounts up to 2 pounds daily per cow without obtaining increases in milk or butterfat production. Sheehy (1931) also reported no increases in butterfat percentage or milk production by the use of several oils.

On the other hand, Nevens et al. (1926) found increases in butterfat content resulting from the addition of some oils to the rations of dairy cattle, but again these increases disappeared after the first 2 or 3 days. Increases in butterfat production were noted by Allen (1934) from results of extensive experimentation on the feeding of rations augmented by adding butterfat, lard, tallow, linseed oil, cottonseed oil, corn oil, peanut oil, soybean oil, or coconut oil. An increase in milk-fat content was noted regardless of breed of cows, stage of lactation, level of production, or season of the year. Milk yield was influenced slightly if at all, except with coconut oil which depressed milk yields when fed in large amounts. The increased yield of butterfat amounted to 10 to 20 percent of the increased fat fed. At high levels of fat feeding, the butterfat tends to assume the characteristics of the fat being fed. Monroe (1951) in his review observed that these investigations gave no satisfactory evidence regarding the effect of continued feeding.

Other conflicting evidence exists. Gibson and Huffman (1939) reported an increase in fat production from adding soybean oil to a low-fat ration. In a later report, however, Huffman and Duncan (1940) stated that the increases from adding soybean oil were not obtained consistently. Similarly, Sutton et al. (1932) found that the ingestion of 1 pound of corn oil per day resulted in no significant changes in milk or butterfat production, whereas Brown and Sutton (1931) found that the feeding of menhaden oil had a definite depressing effect on both butterfat percentage and production. Even the feeding of butterfat in the form of butter or cream failed to result in significant and sustained increases in milk or butterfat production.

Finally, Eskedal (1953) reported that linseed cake and rapeseed cake rich in fats do not increase the fat percentage of milk, but may increase the yield.

Recent results indicate that fat-enriched rations for dairy cattle have slight positive effects. However, these effects are closely interrelated with numerous other dietary factors, such as the relative proportions of starch and roughage. In summarizing, the results of research on adding fats and oils to the rations of dairy cattle indicate that this is an ineffective method for increasing milk and butterfat production.

Calves

Dried skim milk supplemented with vitamins and trace minerals was used as the basic component of some of the earlier milk replacement formulas. As a result of feeding these diets which were very low in fat, calves grew poorly and were low in quality and frequently subject to diarrhea. It is now known that fat is essential in the diet of calves. Cunningham and Loosli (1954) found that calves receiving a fat-free synthetic milk eventually died. The condition could be cured by feeding an artificial milk containing 4 percent of lard and could be prevented by one containing 1 to 2 percent of lard.

Wiese et al. (1947) observed that when soybean oil was used as a source of fat the calves grew poorly and scoured, whereas rations prepared with lard led to normal and healthy animals. Gullickson et al. (1942) found vegetable oils to be an unsatisfactory substitute for butterfat in calf feeding. Jacobson and Cannon (1947) showed that soybean oil could be greatly improved by hydrogenation but even then was not quite as good as lard. In some unpublished work from this laboratory, Riemenschneider (1953)[4] found that lard, an equal mixture of lard and coconut oil, or choice white grease, added to skim milk powder in amounts equivalent to the fat content (26 percent) of dried whole milk, gave growth performance comparable to whole milk when reconstituted with water and fed to 3-day old calves for 7 weeks. Growth was far superior to that obtained with reconstituted skim milk alone. Commercial lecithin (0.5 percent of added fat) was employed as emulsifier. The skim milk-fat mixture was reconstituted on the basis of 1 pound per gallon of water. Thorough emulsification or homogenization was found essential for optimum utilization by the calves. Larsen (1958) reported both lard and tallow were equal to butterfat when homogenized with a milk replacer diet.

Recently Jacobson et al. (1959) reported their findings on the use of milk replacer

[4] Riemenschneider, R.W. Unpublished results. 1953.

formulations containing 18 percent of lard oil. The formulations were reconstituted at feeding time with six parts of water to one part of formula. In general, satisfactory results were obtained and the economic aspects of the matter assumed paramount importance. Lassiter et al. (1958) reported that replacer rations containing 10 percent of added fat gave the best results. With this percentage of added fat in the replacer ration, calves gained in body weight 90 percent faster than on rations containing no added fat. Fat added at 20 or 30 percent levels did not prove so beneficial.

In conclusion, fats are essential elements in milk replacement formulas for calves. In general, animal fats are more successfully utilized than vegetable oils, although hydrogenated vegetable oils have given satisfactory results.

LAMBS AND SHEEP

Kammlade and Butler (1954) reported on the use of animal fats in lamb feeding. Objectives of their tests were to determine the suitability of animal fats as a source of energy in lamb fattening rations, to determine the optimum level of added fat, and to study the effects of increasing the energy content of lamb fattening rations by substituting fats pound for pound for various amounts of the grain portion of the ration. Sixty Texas finewool lambs were divided into four lots and fed rations containing 0, 5, 10, and 15 percent of added fat, respectively. The results indicate that animal fats are satisfactory sources of energy in lamb fattening rations and that the optimum level to incorporate is 5 to 10 percent. Lambs fed a ration containing 5 percent of added animal fat made the highest, most efficient, and cheapest gains. Their dressing percentages and carcass grades were also the highest.

Brethour et al. (1958) found that animal fat at level of 15 percent in the ration significantly reduced digestibility and weight gains; corn oil at 10 percent reduced gains and caused frothy foam in the rumen. An explanation of the mechanism of this reduced digestibility may be found in the work of White et al. (1958). These investigators found that corn oil at 5 percent levels in the ration progressively decreased cellulose digestion during a 40-day trial. Full recovery of cellulose digestion was not complete until 17 days after omission of the corn oil.

DOGS

It has been stated by Heiman (1959) that there are about 25 million dogs in the United States at the present time. These dogs consume more than 6,000 tons of food each day on a dry basis. Of course, not all dogs are fed a prepared dog food, and the above figures include both dry and canned foods. Schweigert et al. (1952) at the American Meat Institute in cooperation with the U.S. Department of Agriculture selected dry dog food for early nutritional investigation as second only to poultry rations in potentialities for the effective use of byproduct animal fats. In 1947 conservative estimates showed that 340,000 tons of dry dog meals were produced annually in the United States. Commercial dry dog meals contained only about 5 percent of fat as contrasted with a much higher level of dietary fat included in canned dog foods, usually 10 to 15 percent. It was generally supposed that a higher level of fat in dry dog foods would be desirable from a nutritional viewpoint but might lead to rancidity losses.

Results of the first systematic study of the growth performance of dogs fed graded levels of fat added to a basal diet comprised of ingredients commonly used in commercial dry meals were reported by Siedler and Schweigert (1952). They investigated the rate of gain of young cocker spaniel pups fed diets with and without added choice white grease stabilized with an antioxidant. When 4, 6, or 8 percent of fat was added to the basal diet or when 6 percent of fat was added to a commercial meal, the rates of gain for a 10-week period were equal or slightly superior to those obtained when the diets without added fat were fed. No significant differences in the food or caloric efficiencies were noted between the groups fed different levels of fat, an indication that the calories from the fat were well utilized. No reluctance to consume the rations was reported.

Subsequent investigations showed that a ration in which the energy content was increased by adding fat requires a careful formulation of the amino acid composition or a higher level of good quality protein to meet the dietary needs of the growing pup. Campbell and Phillips (1953) found that adding fat to a ration which already contained 4 percent of fat inhibited growth of carefully selected mongrel weanling pups and that the normal growth rate was resumed when 0.3 percent of methionine was

added. Ontko et al. (1957) extended these studies and reported that mixed groups of beagle, shepherd, and shepherd-collie pups on a diet containing 20 percent of lard required 25 percent of good quality protein to show a maximum growth response. When the dietary fat content was raised to 30 percent, the rate of growth increased as the dietary protein was increased to 28.9 percent. The food efficiency was distinctly superior with the 30 percent fat diet over that with the 20 percent fat diet. Thus, it is apparent with growing dogs that a ration having a high fat content may be used if other nutrients (and particularly protein and amino acids) are present in adequate amounts.

Siedler and Schweigert (1954a) extended their previous studies on cocker spaniel pups. The females were maintained in the same feeding groups as before on a basal ration with or without 4 or 8 percent of stabilized choice white grease or 18 percent of sucrose. The females showed excellent maintenance, reproduction, and lactation on the dry rations containing 4 percent of added fat. Efficiency of the basal ration for maintenance of the females before breeding was increased by the addition of animal fat. The reproduction performance of females receiving the basal ration with 4 percent of added fat was somewhat better than those on the basal ration alone. The addition of 8 percent of fat to the basal ration appeared to reduce the reproductive capacity as judged by the number of pups dead after 24 hours and the weight of pups at birth, although this may have been influenced by the larger number of pups per litter. Females fed rations with 18 percent of added sucrose showed poor reproductive capacity. The average rate of gain of pups from females fed 4 percent of added fat was highest of all groups, whereas the gain of pups from females receiving 8 percent of fat or 18 percent of sucrose was slightly less than that for pups from females receiving the basal rations.

Hansen et al. (1951, 1954) reported that dogs and especially young puppies were extremely sensitive to a deficiency of fat in a diet. A simplified diet containing only 0.9 percent of fat produced a dry hair coat and flaking skin. This was followed by loss of hair, peeling of skin, reddening of the paws, and edema and oozing between the toes. These deficiency symptoms are thought to be due to a lack of essential fatty acids such as linoleic and arachidonic acid. However, complete and permanent reversal of these symptoms was not observed where fat made up less than 8 to 15 percent of the diet.

MINK

Considerable interest in the use of fats in the feeding of mink has developed recently. The amount of fat that can be used in mink rations is still the subject of a considerable difference of opinion. Travis and Schaible (1958) consider commercial mink rations to be about optimum, on the basis of current feeding methods. These rations contain from 15 to 25 percent of fat (on a dry basis) during the growing season and from 15 to 20 percent during breeding and gestation season. On the other hand, Wood (1956) states that "there appears to be no question that the mink can handle fat levels as high as 30 or even 40 percent of the ration." He is of the opinion that the oxidation of unsaturated fats and the concurrent oxidation of other essential nutrients, such as vitamin E and thiamine, present more of a problem.

Current methods of feeding mink, which involve the use of large amounts of fresh or frozen horse meat, whale meat, fish, and byproducts of livestock-, poultry-, and fish-processing industries, are expensive and provide opportunities for careless handling which results in oxidation of the fat components and degradation of other nutrients. Processing of these animal products by cooking or drying reduces digestibility. Nevertheless, the development of a successful, all-purpose dry ration composed of readily available and stabilized dry ingredients is highly desirable.

The rations used by Wood are presented in table 15. The rations for kit mink and breeder mink contain 10 percent of stabilized edible fat, whereas those for stock mink contain only $2\frac{1}{2}$ percent. Rations for breeder mink maintained adults in excellent condition when self-fed in crumble form if supplemented once a week by 2 ounces of fresh liver.

Kifer and Schaible (1956) prepared stable and easily stored dried rations which were satisfactory only for adult mink during nutritionally noncritical periods of the year. However, when 4 or 6 percent of cottonseed

TABLE 15.--*Rations for stock, breeder, and kit mink*[1]

Ration constituent	Mink stock[2]	Mink breeder[3]	Kit mink[4]
—	*Pounds*	*Pounds*	*Pounds*
Wheat (medium fine grind)	870	280	300
Oatmeal (medium fine grind)	370	280	300
Fish meal (herring)	200	400	400
Soybean meal (44%)	200	300	400
Cerelose	--	100	60
Skim milk powder	100	200	200
Edible fat (stabilized)	50	200	100
Wheat bran	100	100	100
Distillers solubles	30	40	40
Brewers yeast	20	30	30
Bone meal	10	20	20
Salt (iodized)	10	10	10
Apple pomace	20	20	20
Vitamin premix	20	20	20

[1] Adapted from Wood (1958).
[2] To be fed as 40 percent of final feed mix from September 1 to January 15.
[3] To be fed as 30 percent of final feed mix from January 15 to September 1.
[4] To be fed as 35 percent of final feed mix from weaning at 8 weeks until September 1.

oil was added to these dried rations, the results obtained during the late growth period of kit mink (10 weeks to pelting) were equal or superior to those obtained when a "wet" ranch-type ration was fed.

Worne (1957, 1958) reported that mink have a very high requirement for essential fatty acids. Lack of essential fatty acids in the diet of female breeder mink resulted in poor reproduction and failure in lactation with the resulting death of mink kits. Analysis of the blood of mink suffering from yellow fat disease, Aleutian disease and wet belly (diseases involved in the metabolic malfunctioning of fat) showed a marked reduction in levels of essential fatty acids, as well as vitamins A, C, and E. Blood samples from wild mink were found to contain levels of essential fatty acids consistently higher than that of presumably healthy ranch mink. Many of the meat products ordinarily contain adequate amounts of essential fatty acids. However, when Worne (1958) assayed samples of various meat products provided to mink ranchers, the fat in many cases was rancid and the essential fatty acids had been destroyed by oxidation. Another result of fat oxidation is the concurrent destruction of vitamins associated with it in the ration.

Yellow fat disease (steatitis) of young mink is associated with the feeding of stored horse meat or fish, or of excessive amounts of fish or fish scrap. It has been produced experimentally by feeding ordinary ranch rations containing 3 percent of linolenic acid (as raw linseed oil) (Wisconsin 1952). According to Hartsough and Gorham (1958) recent work indicates the disease is caused by a low level of vitamin E and a substantial amount of unsaturated fatty acids in the diet.

The feces of mink suffering from Aleutian disease (grey diarrhea) contain a high percentage of residual unmetabolized fat having a rather high peroxide number. This disease usually results in death, although Worne (1958) reported that in experiments on diets with a reduced fat content favorable results were obtained on a significant number of afflicted mink.

Wet belly (wet sheath) disease is characterized by urinary incontinence and results in permanent discoloration of the fur, thus reducing its value. Its origin is unknown, but Leoschke (1958) showed that its incidence may be reduced by placing young mink, whose genetic background predisposes them to the disease, on a low-fat diet beginning about the first of October.

The feeding of poultry and beef cattle byproducts containing diethylstilbesterol and related drugs has produced sterility in breeder mink causing severe financial losses. While these have, in the past, been introduced into mink rations primarily in the form of meat products, renderers should scrupulously avoid animal byproducts known to contain these powerful drugs where any of the fat might find its way into mink rations.

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